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(54) HYDROXY-SUBSTITUTED AZETIDINONE COMPOUNDS USEFUL AS  
HYPOCHOLESTEROLEMIC AGENTS

HYDROXY-SUBSTITUIERTE AZETIDINONDERIVATE ALS HYPOCHOLESTEROLEMISCHE  
MITTEL

COMPOSES D'AZETIDINONE HYDROXY-SUBSTITUES EFFICACES EN TANT QU'AGENTS  
HYPOCHOLESTEROLEMIQUES

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AL. 'Synthesis and stereochemistry of  
3-(alpha-hydroxybenzyl)  
-1,4-diphenyl-2-azetidinones.'

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## Description

BACKGROUND OF THE INVENTION

5 [0001] The present invention relates to hydroxy-substituted azetidinones useful as hypocholesterolemic agents in the treatment and prevention of atherosclerosis, and to the combination of a hydroxy-substituted azetidinone of this invention and a cholesterol biosynthesis inhibitor for the treatment and prevention of atherosclerosis. The invention also relates to a process for preparing hydroxy-substituted azetidinones.

10 [0002] Atherosclerotic coronary heart disease (CHD) represents the major cause for death and cardiovascular morbidity in the western world. Risk factors for atherosclerotic coronary heart disease include hypertension, diabetes mellitus, family history, male gender, cigarette smoke and serum cholesterol. A total cholesterol level in excess of 225-250 mg/dl is associated with significant elevation of risk of CHD.

[0003] Cholesteryl esters are a major component of atherosclerotic lesions and the major storage form of cholesterol in arterial wall cells. Formation of cholesteryl esters is also a key step in the intestinal absorption of dietary cholesterol. 15 Thus, inhibition of cholesteryl ester formation and reduction of serum cholesterol is likely to inhibit the progression of atherosclerotic lesion formation, decrease the accumulation of cholesteryl esters in the arterial wall, and block the intestinal absorption of dietary cholesterol.

[0004] A few azetidinones have been reported as being useful in lowering cholesterol and/or in inhibiting the formation of cholesterol-containing lesions in mammalian arterial walls. U.S. 4,983,597 discloses N-sulfonyl-2-azetidinones as anticholesterol agents and Ram, et al., in *Indian J. Chem., Sect. B*, 29B, 12 (1990), p. 1134-7, disclose ethyl 4-(2-oxoazetidin-4-yl)phenoxy-alkanoates as hypolipidemic agents. European Patent Publication 264,231 discloses 1-substituted-4-phenyl-3-(2-oxo-alkylidene)-2-azetidinones as blood platelet aggregation inhibitors. European Patent 199,630 and European Patent Application 337,549 disclose elastase inhibitory substituted azetidinones said to be 25 useful in treating inflammatory conditions resulting in tissue destruction which are associated with various disease states, e.g. atherosclerosis.

[0005] WO93/02048, published February 4, 1993, discloses substituted  $\beta$ -lactams useful as hypocholesterolemic agents.

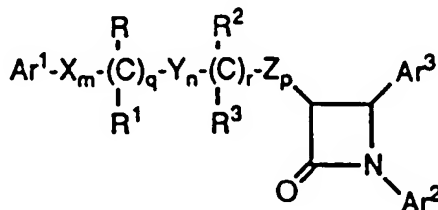
30 [0006] The regulation of whole-body cholesterol homeostasis in humans and animals involves the regulation of dietary cholesterol and modulation of cholesterol biosynthesis, bile acid biosynthesis and the catabolism of the cholesterol-containing plasma lipoproteins. The liver is the major organ responsible for cholesterol biosynthesis and catabolism and for this reason, it is a prime determinant of plasma cholesterol levels. The liver is the site of synthesis and secretion of very low density lipoproteins (VLDL) which are subsequently metabolized to low density lipoproteins (LDL) in the circulation. LDL are the predominant cholesterol-carrying lipoproteins in the plasma and an increase in their concentration is correlated with increased atherosclerosis.

35 [0007] When intestinal cholesterol absorption is reduced, by whatever means, less cholesterol is delivered to the liver. The consequence of this action is decreased hepatic lipoprotein (VLDL) production and an increase in the hepatic clearance of plasma cholesterol, mostly as LDL. Thus, the net effect of inhibiting intestinal cholesterol absorption is a decrease in plasma cholesterol levels.

40 [0008] The inhibition of cholesterol biosynthesis by 3-hydroxy-3-methylglutaryl coenzyme A (HMG CoA) reductase (EC1.1.1.34) inhibitors has been shown to be an effective way to reduce plasma cholesterol (Witzum, *Circulation*, 80, 5 (1989), p. 1101-1114) and reduce atherosclerosis. Combination therapy of an HMG CoA reductase inhibitor and a bile acid sequestrant has been demonstrated to be more effective in human hyperlipidemic patients than either agent in monotherapy (Illingworth, *Drugs*, 36 (Suppl. 3) (1988), p. 63-71).

45 SUMMARY OF THE INVENTION

[0009] Novel hypocholesterolemic compounds of the present invention are represented by the formula I



or a pharmaceutically acceptable salt thereof, wherein:

Ar<sup>1</sup> and Ar<sup>2</sup> are independently selected from the group consisting of aryl and R<sup>4</sup>-substituted aryl;

Ar<sup>3</sup> is aryl or R<sup>5</sup>-substituted aryl;

5 X, Y and Z are independently selected from the group consisting of -CH<sub>2</sub>-, -CH(C<sub>1</sub>-C<sub>6</sub> alkyl)- and -C(di(C<sub>1</sub>-C<sub>6</sub> alkyl))-;

R and R<sup>2</sup> are independently selected from the group consisting of -OR<sup>6</sup>, -O(CO)R<sup>6</sup>, -O(CO)OR<sup>9</sup> and -O(CO)NR<sup>6</sup>R<sup>7</sup>;

R<sup>1</sup> and R<sup>3</sup> are independently selected from the group consisting of hydrogen, C<sub>1</sub>-C<sub>6</sub> alkyl and aryl;

10 q is 0 or 1; r is 0 or 1; m, n and p are independently 0, 1, 2, 3 or 4; provided that at least one of q and r is 1, and the sum of m, n, p, q and r is 1, 2, 3, 4, 5 or 6; and provided that when p is 0 and r is 1, the sum of m, q and n is 1, 2, 3, 4 or 5;

R<sup>4</sup> is 1-5 substituents independently selected from the group consisting of C<sub>1</sub>-C<sub>6</sub> alkyl, -OR<sup>6</sup>, -O(CO)R<sup>6</sup>, -O(CO)OR<sup>9</sup>, -O(CH<sub>2</sub>)<sub>1-5</sub>OR<sup>6</sup>, -O(CO)NR<sup>6</sup>R<sup>7</sup>, -NR<sup>6</sup>R<sup>7</sup>, -NR<sup>6</sup>(CO)R<sup>7</sup>, -NR<sup>6</sup>(CO)OR<sup>9</sup>, -NR<sup>6</sup>(CO)NR<sup>7</sup>R<sup>8</sup>, -NR<sup>6</sup>SO<sub>2</sub>R<sup>9</sup>, -COOR<sup>6</sup>, -CONR<sup>6</sup>R<sup>7</sup>, -COR<sup>6</sup>, -SO<sub>2</sub>NR<sup>6</sup>R<sup>7</sup>, S(O)<sub>0-2</sub>R<sup>9</sup>, -O(CH<sub>2</sub>)<sub>1-10</sub>-COOR<sup>6</sup>, -O(CH<sub>2</sub>)<sub>1-10</sub>CONR<sup>6</sup>R<sup>7</sup>, -(C<sub>1</sub>-C<sub>6</sub> alkylene)COOR<sup>6</sup>, -CH=CH-COOR<sup>6</sup>, -CF<sub>3</sub>, -CN, -NO<sub>2</sub> and halogen;

15 R<sup>5</sup> is 1-5 substituents independently selected from the group consisting of -OR<sup>6</sup>, -O(CO)R<sup>6</sup>, -O(CO)OR<sup>9</sup>, -O(CH<sub>2</sub>)<sub>1-5</sub>OR<sup>6</sup>, -O(CO)NR<sup>6</sup>R<sup>7</sup>, -NR<sup>6</sup>R<sup>7</sup>, -NR<sup>6</sup>(CO)R<sup>7</sup>, -NR<sup>6</sup>(CO)OR<sup>9</sup>, -NR<sup>6</sup>(CO)NR<sup>7</sup>R<sup>8</sup>, -NR<sup>6</sup>SO<sub>2</sub>R<sup>9</sup>, -COOR<sup>6</sup>, -CONR<sup>6</sup>R<sup>7</sup>, -COR<sup>6</sup>, -SO<sub>2</sub>NR<sup>6</sup>R<sup>7</sup>, S(O)<sub>0-2</sub>R<sup>9</sup>, -O(CH<sub>2</sub>)<sub>1-10</sub>-COOR<sup>6</sup>, -O(CH<sub>2</sub>)<sub>1-10</sub>CONR<sup>6</sup>R<sup>7</sup>, -(C<sub>1</sub>-C<sub>6</sub> alkylene)COOR<sup>6</sup> and -CH=CH-COOR<sup>6</sup>;

20 R<sup>6</sup>, R<sup>7</sup> and R<sup>8</sup> are independently selected from the group consisting of hydrogen, C<sub>1</sub>-C<sub>6</sub> alkyl, aryl and aryl-substituted C<sub>1</sub>-C<sub>6</sub> alkyl; and

R<sup>9</sup> is C<sub>1</sub>-C<sub>6</sub> alkyl, aryl or aryl-substituted C<sub>1</sub>-C<sub>6</sub> alkyl; wherein aryl is phenyl, naphthyl, indenyl, tetrahydronaphthyl or indanyl.

25 [0010] R<sup>4</sup> is preferably 1-3 independently selected substituents, and R<sup>5</sup> is preferably 1-3 independently selected substituents. Preferred are compounds of formula I wherein Ar<sup>1</sup> is phenyl or R<sup>4</sup>-substituted phenyl, especially (4-R<sup>4</sup>)-substituted phenyl. Ar<sup>2</sup> is preferably phenyl or R<sup>4</sup>-substituted phenyl, especially (4-R<sup>4</sup>)-substituted phenyl. Ar<sup>3</sup> is preferably R<sup>5</sup>-substituted phenyl, especially (4-R<sup>5</sup>)-substituted phenyl. When Ar<sup>1</sup> is (4-R<sup>4</sup>)-substituted phenyl, R<sup>4</sup> is preferably a halogen. When Ar<sup>2</sup> and Ar<sup>3</sup> are R<sup>4</sup>- and R<sup>5</sup>-substituted phenyl, respectively, R<sup>4</sup> is preferably halogen or -OR<sup>6</sup> and R<sup>5</sup> is preferably -OR<sup>6</sup>, wherein R<sup>6</sup> is C<sub>1</sub>-C<sub>6</sub> alkyl or hydrogen. Especially preferred are compounds wherein each of Ar<sup>1</sup> and Ar<sup>2</sup> is 4-fluorophenyl and Ar<sup>3</sup> is 4-hydroxyphenyl or 4-methoxyphenyl.

30 [0011] X, Y and Z are each preferably -CH<sub>2</sub>-. R<sup>1</sup> and R<sup>3</sup> are each preferably hydrogen. R and R<sup>2</sup> are preferably -OR<sup>6</sup> wherein R<sup>6</sup> is hydrogen, or a group readily metabolizable to a hydroxyl (such as -O(CO)R<sup>6</sup>, -O(CO)OR<sup>9</sup> and -O(CO)NR<sup>6</sup>R<sup>7</sup>, defined above).

35 [0012] The sum of m, n, p, q and r is preferably 2, 3 or 4, more preferably 3. Preferred are compounds wherein m, n and r are each zero, q is 1 and p is 2. Also preferred are compounds wherein p, q and n are each zero, r is 1 and m is 2 or 3. More preferred are compounds wherein m, n and r are each zero, q is 1, p is 2, Z is -CH<sub>2</sub>- and R is -OR<sup>6</sup>, especially when R<sup>6</sup> is hydrogen. Also more preferred are compounds wherein p, q and n are each zero, r is 1, m is 2, X is -CH<sub>2</sub>- and R<sup>2</sup> is -OR<sup>6</sup>, especially when R<sup>6</sup> is hydrogen.

40 [0013] Another group of preferred compounds is that wherein Ar<sup>1</sup> is phenyl or R<sup>4</sup>-substituted phenyl, Ar<sup>2</sup> is phenyl or R<sup>4</sup>-substituted phenyl and Ar<sup>3</sup> is R<sup>5</sup>-substituted phenyl. Also preferred are compounds wherein Ar<sup>1</sup> is phenyl or R<sup>4</sup>-substituted phenyl, Ar<sup>2</sup> is phenyl or R<sup>4</sup>-substituted phenyl, Ar<sup>3</sup> is R<sup>5</sup>-substituted phenyl, and the sum of m, n, p, q and r is 2, 3 or 4, more especially 3. More preferred are compounds wherein Ar<sup>1</sup> is phenyl or R<sup>4</sup>-substituted phenyl, Ar<sup>2</sup> is phenyl or R<sup>4</sup>-substituted phenyl, Ar<sup>3</sup> is R<sup>5</sup>-substituted phenyl, and wherein m, n and r are each zero, q is 1 and p is 2, or wherein p, q and n are each zero, r is 1 and m is 2 or 3.

45 [0014] This invention also relates to a method of lowering the serum cholesterol level in a mammal in need of such treatment comprising administering an effective amount of a compound of formula I. That is, the use of a compound of the present invention as an hypocholesterolemic agent is also claimed.

[0015] In still another aspect, the present invention relates to a pharmaceutical composition comprising a serum cholesterol-lowering effective amount of a compound of formula I in a pharmaceutically acceptable carrier.

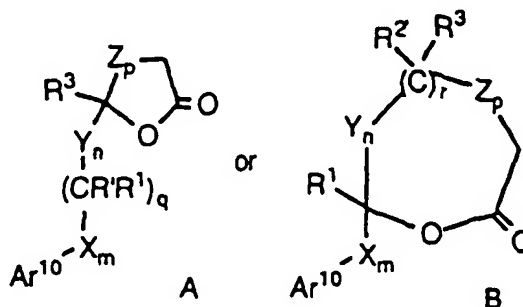
50 [0016] The present invention also relates to a method of reducing plasma cholesterol levels, and to a method of treating or preventing atherosclerosis, comprising administering to a mammal in need of such treatment an effective amount of a combination of a hydroxy-substituted azetidinone cholesterol absorption inhibitor of formula I and a cholesterol biosynthesis inhibitor. That is, the present invention relates to the use of a hydroxy-substituted azetidinone cholesterol absorption inhibitor of formula I for combined use with a cholesterol biosynthesis inhibitor (and, similarly, use of a cholesterol biosynthesis inhibitor for combined use with a hydroxy-substituted azetidinone cholesterol absorption inhibitor of formula I) to treat or prevent atherosclerosis or to reduce plasma cholesterol levels.

55 [0017] In yet another aspect, the invention relates to a pharmaceutical composition comprising an effective amount

of a hydroxy-substituted azetidinone cholesterol absorption inhibitor of formula I, a cholesterol biosynthesis inhibitor, and a pharmaceutically acceptable carrier. In a final aspect, the invention relates to a kit comprising in one container an effective amount of a hydroxy-substituted azetidinone cholesterol absorption inhibitor of formula I in a pharmaceutically acceptable carrier, and in a separate container, an effective amount of a cholesterol biosynthesis inhibitor in a pharmaceutically acceptable carrier.

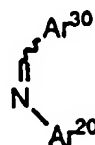
[0018] In yet another aspect, the invention relates to a process for preparing certain compounds of formula I comprising the steps:

(a) treating with a strong base a lactone of the formula



wherein R' and R2' are R and R2, respectively, or are suitably protected hydroxy groups; Ar10 is Ar1, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl; and the remaining variables are as defined above, provided that in lactone of formula B, when n and r are each zero, p is 1-4;

(b) reacting the product of step (a) with an imine of the formula



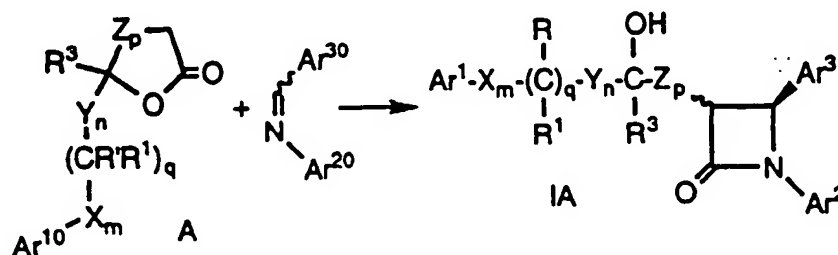
wherein Ar20 is Ar2, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl; and Ar30 is Ar3, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl;

c) quenching the reaction with an acid;

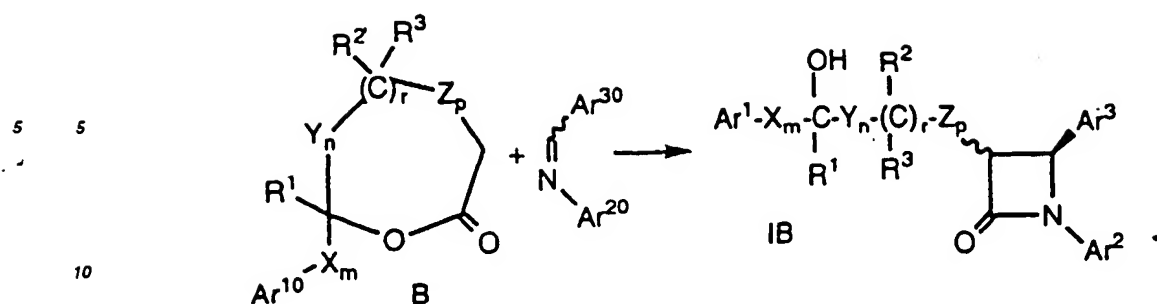
d) optionally removing the protecting groups from R', R2', Ar10, Ar20 and Ar30, when present; and

e) optionally functionalizing hydroxy or amino substituents at R, R2, Ar1, Ar2 and Ar3.

[0019] Using the lactones shown above, compounds of formula IA and IB are obtained as follows:



wherein the variables are as defined above; and



wherein the variables are as defined above.

# 15 DETAILED DESCRIPTION:

[0020] As used herein, the term "lower alkyl" means straight or branched alkyl chains of 1 to 6 carbon atoms.

[0021] "Aryl" means phenyl, naphthyl, indenyl, tetrahydronaphthyl or indanyl.

[0022] "Halogeno" refers to fluorine, chlorine, bromine or iodine atoms.

20 [0023] The above statement, wherein R<sup>6</sup>, R<sup>7</sup> and R<sup>8</sup> are said to be independently selected from a group of substituents, means that R<sup>6</sup>, R<sup>7</sup> and R<sup>8</sup> are independently selected, but also that where an R<sup>6</sup>, R<sup>7</sup> or R<sup>8</sup> variable occurs more than once in a molecule, those occurrences are independently selected (e.g., if R is -OR<sup>6</sup> wherein R<sup>6</sup> is hydrogen, R<sup>4</sup> can be -OR<sup>6</sup> wherein R<sup>6</sup> is lower alkyl).

25 [0024] Compounds of the invention have at least one asymmetric carbon atom and therefore all isomers, including enantiomers and diastereomers are contemplated as being part of this invention. The invention includes d and l isomers in both pure form and in admixture, including racemic mixtures. Isomers can be prepared using conventional techniques, either by reacting chiral starting materials or by separating isomers of a compound of formula I. Isomers may also include geometric isomers, e.g. when a double bond is present. All such geometric isomers are contemplated for this invention.

30 [0025] Those skilled in the art will appreciate that for some compounds of formula I, one isomer will show greater pharmacological activity than another isomer.

35 [0026] Compounds of the invention with an amino group can form pharmaceutically acceptable salts with organic and inorganic acids. Examples of suitable acids for salt formation are hydrochloric, sulfuric, phosphoric, acetic, citric, oxalic, malonic, salicylic, malic, fumaric, succinic, ascorbic, maleic, methanesulfonic and other mineral and carboxylic acids well known to those in the art. The salt is prepared by contacting the free base form with a sufficient amount of the desired acid to produce a salt. The free base form may be regenerated by treating the salt with a suitable dilute aqueous base solution such as dilute aqueous sodium bicarbonate. The free base form differs from its respective salt form somewhat in certain physical properties, such as solubility in polar solvents, but the salt is otherwise equivalent to its respective free base form for purposes of the invention.

40 [0027] Certain compounds of the invention are acidic (e.g., those compounds which possess a carboxyl group). These compounds form pharmaceutically acceptable salts with inorganic and organic bases. Examples of such salts are the sodium, potassium, calcium, aluminum, gold and silver salts. Also included are salts formed with pharmaceutically acceptable amines such as ammonia, alkyl amines, hydroxyalkylamines, N-methylglucamine and the like.

45 [0028] Cholesterol biosynthesis inhibitors for use in the combination of the present invention include HMG CoA reductase inhibitors such as lovastatin, pravastatin, fluvastatin, simvastatin, and CI-981; HMG CoA synthetase inhibitors, for example L-659,699 ((E,E)-11-[3'R-(hydroxymethyl)-4'-oxo-2'R-oxetanyl]-3,5,7R-trimethyl-2,4-undecadienoic acid); squalene synthesis inhibitors, for example squalastatin 1; and squalene epoxidase inhibitors, for example, NB-598 ((E)-N-ethyl-N-(6,6-dimethyl-2-hepten-4-ynyl)-3-[(3,3'-bithiophen-5-yl)methoxy]benzene-methanamine hydrochloride) and other cholesterol biosynthesis inhibitors such as DMP-565. Preferred HMG CoA reductase inhibitors are lovastatin, pravastatin and simvastatin.

50 [0029] Compounds of formula I can be prepared by known methods, for example those described below and in WO93/02048.

## Method A:

[0032]

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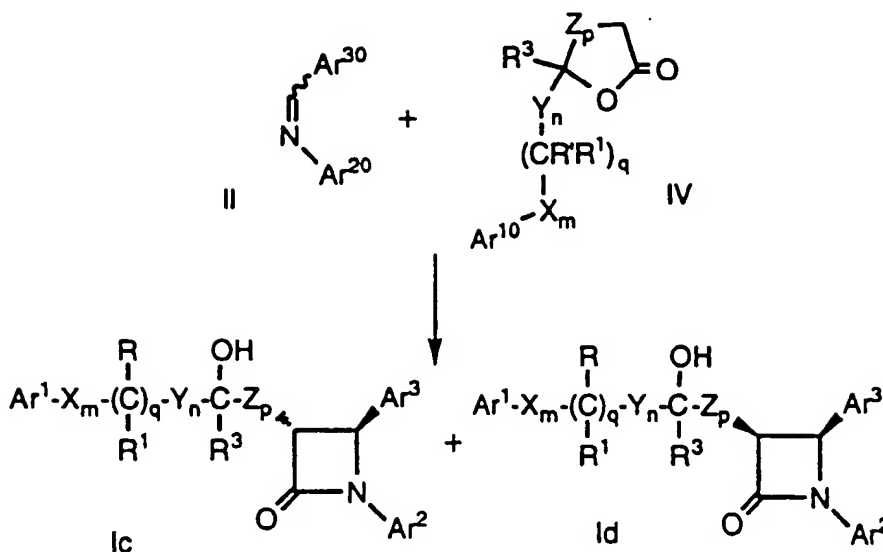
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Compounds of formula 1c and 1d, wherein the variables are as defined above, can be prepared by a process comprising the following steps:

(a) Treat a lactone of formula IV, wherein the variables are as defined above, with a strong base such as an alkyl lithium (e.g., n-butyllithium), a metal hydride (e.g., sodium hydride), a metal alkoxide (e.g., sodium methoxide), a metal halide (e.g.,  $\text{TiCl}_4$ ), metal exchange of the lithium enolate with a metal halide (e.g., zinc chloride), metal exchange of the lithium enolate with a metal alkyl (e.g., 9-borabicyclononyl triflate), or, preferably, a metalamide (e.g., LDA), in a suitable anhydrous organic solvent such as dry THF, ether or benzene, in a dry, inert atmosphere, e.g., under nitrogen. The reaction is carried out at about  $0^\circ\text{C}$  to about  $-85^\circ\text{C}$ , preferably about  $-78^\circ\text{C}$ , over a period of about 5 to about 60 minutes, preferably about 30 minutes. 1-50% of solubilizing cosolvents may optionally be added, preferably about 10% HMPA.

(b) Add an imine of formula II, wherein  $\text{Ar}^{20}$  and  $\text{Ar}^{30}$  are as defined above, to the product of step (a) over a period of 5 to 60 minutes, preferably 30 minutes, maintaining the reaction mixture at about  $0^\circ\text{C}$  to about  $-85^\circ\text{C}$ , preferably about  $-78^\circ\text{C}$ , for 1 to 12 hours, preferably about 3 hours, or warming the reaction mixture over that time period at a rate of about  $10^\circ\text{C}$  per hour to about  $70^\circ\text{C}$  per hour, preferably about  $30^\circ\text{C}$  per hour, to a temperature of about  $20^\circ\text{C}$ .

(c) Quench the reaction with a suitable acid such as HCl (1N).

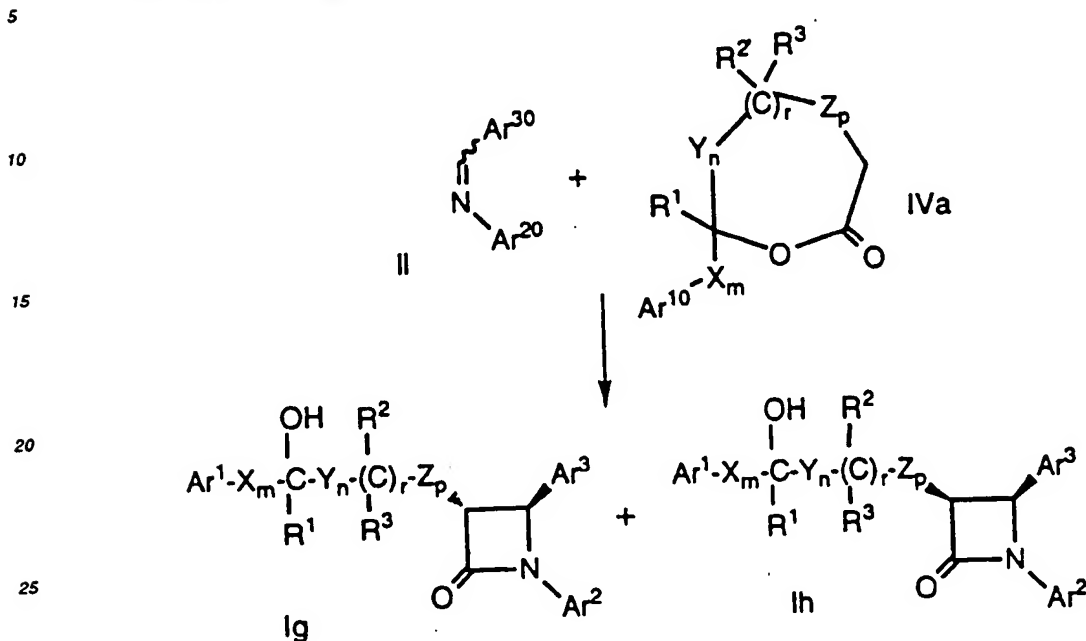
(d) The protecting groups on  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{Ar}^{10}$ ,  $\text{Ar}^{20}$  and  $\text{Ar}^{30}$ , when present, are removed, if desired, by methods well known in the art, for example silyl protecting groups are removed by treatment with fluoride.

(e) Compounds of formula I wherein any of  $\text{R}$  and  $\text{R}^2$ , when present, are  $\text{OR}^6$  wherein  $\text{R}^6$  is hydrogen, can be converted by well known methods to other compounds of formula I wherein  $\text{R}$  and  $\text{R}^2$  are functionalized, i.e., are independently selected from the group consisting of  $\text{OR}^{6a}$ ,  $-\text{O}(\text{CO})\text{R}^6$ ,  $-\text{O}(\text{CO})\text{OR}^9$  and  $-\text{O}(\text{CO})\text{NR}^6\text{R}^7$ , wherein  $\text{R}^6$ ,  $\text{R}^7$  and  $\text{R}^9$  are as defined above and  $\text{R}^{6a}$  is lower alkyl, aryl, or aryl-lower alkyl. For example, treatment of the alcohol with an alkyl halide in the presence of a suitable base such as NaH will afford alkoxy-substituted compounds (i.e.,  $\text{R}$  or  $\text{R}^2$  is  $\text{OR}^6$ , wherein  $\text{R}^6$  is lower alkyl); treatment of the alcohol with an acylating agent such as acetylchloride will result in compounds wherein  $\text{R}$  or  $\text{R}^2$  is  $-\text{O}(\text{CO})\text{R}^6$ ; treatment of the alcohol with phosgene followed by an alcohol of the formula  $\text{HOR}^9$  affords compounds substituted with a  $-\text{O}(\text{CO})\text{OR}^9$  group; and treatment of the alcohol with phosgene followed by an amine of the formula  $\text{HNR}^6\text{R}^7$  affords compounds wherein  $\text{R}$  or  $\text{R}^2$  is  $-\text{O}(\text{CO})\text{NR}^6\text{R}^7$ . Compounds of formula I wherein any of  $\text{Ar}^1$ ,  $\text{Ar}^2$  or  $\text{Ar}^3$  has a hydroxy or amino group can be similarly functionalized to obtain other compounds of formula I, i.e., wherein  $\text{R}^4$  and  $\text{R}^5$  are independently  $-\text{OR}^{6a}$ ,  $-\text{O}(\text{CO})\text{R}^6$ ,  $-\text{O}(\text{CO})\text{OR}^9$ ,  $-\text{O}(\text{CH}_2)_{1-5}\text{OR}^6$ ,  $-\text{O}(\text{CO})\text{NR}^6\text{R}^7$ ,  $-\text{NR}^6\text{R}^7$ ,  $-\text{NR}^6(\text{CO})\text{R}^7$ ,  $-\text{NR}^6(\text{CO})\text{OR}^9$ ,  $-\text{NR}^6(\text{CO})\text{NR}^7\text{R}^9$  or  $-\text{NR}^6\text{SO}_2\text{R}^9$ .

[0033] The product of step (d) or (e) is isolated using conventional purification techniques such as extraction, crys-

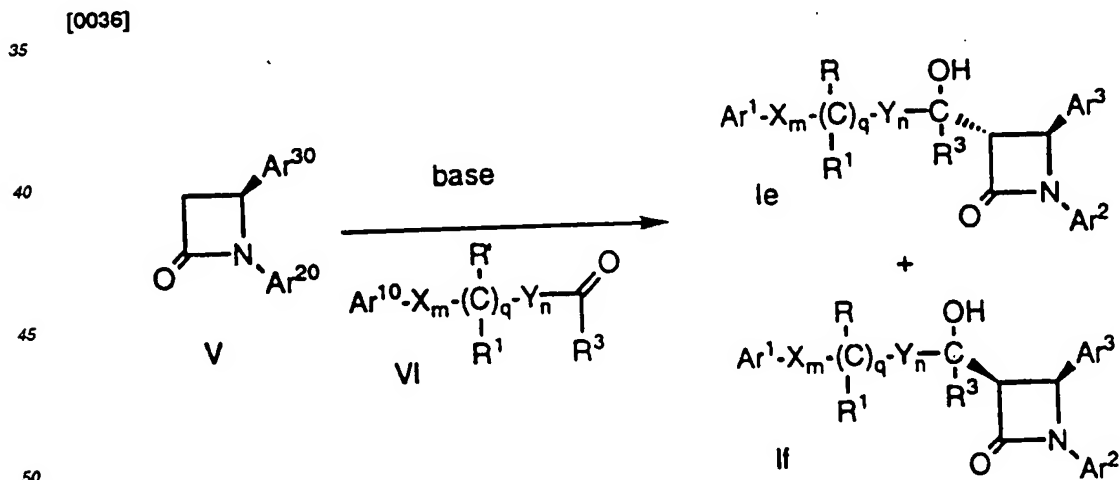
tallization or, preferably, silica gel 60 chromatography. When a chiral lactone is used, the resulting compound of formula Ic or Id is not racemic.

[0034] Using the procedure described in steps (a)-(e), lactones of formula IVa can be used to prepare compounds of formula Ig and Ih, provided that when n and r are each zero, p is 1-4:



[0035] Lactones of formulae IV and IVa are known in the art or can be prepared by methods well known in the art. See, for example, U.S. Patent 4,375,475 and *J. Agric. Food Chem.*, 30 (5) (1982) p. 920-4.

#### Method B:

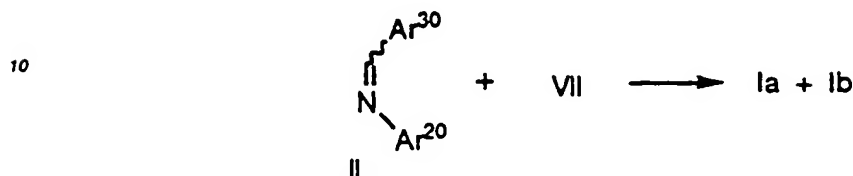


Azetidinones of formula V, wherein Ar<sup>20</sup> and Ar<sup>30</sup> are as defined above, can be reacted to form compounds of formula Ie and If (i.e., compounds of formula I wherein r is 1, R<sup>2</sup> is hydroxy, and p is zero) by treatment of azetidinone V with a strong base such as lithium isopropylcyclohexylamide in a suitable solvent such as THF in the presence or absence of HMPA at -78°C, followed by the addition of an aldehyde or ketone of VI, wherein Ar<sup>10</sup>, X, Y, R<sup>1</sup>, R<sup>3</sup>, m, n and q are as defined above. As in the case of Method A, protecting groups at Ar<sup>10</sup>, Ar<sup>20</sup>, Ar<sup>30</sup>, R<sup>1</sup> and R<sup>2</sup> are removed as necessary.

a dialkylazodicarboxylate. As in the case of Method A, protecting groups at  $Ar^{10}$ ,  $Ar^{20}$ ,  $Ar^{30}$ ,  $R^1$  and  $R^2$  are removed as necessary. This procedure is described in detail in WO93/02048.

#### Method D:

[0039]



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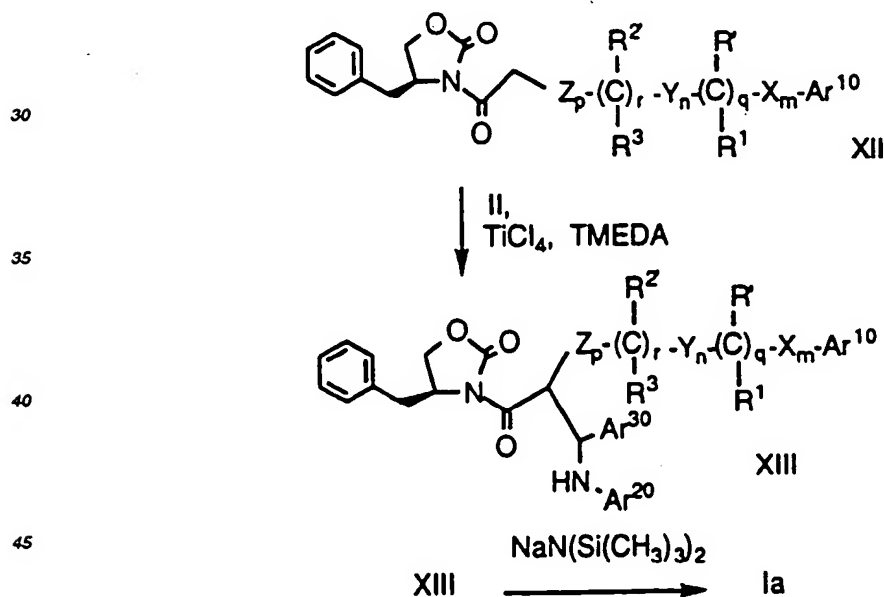
Compounds of formula Ia as defined above can also be prepared by treatment of an imine of formula II, wherein  $Ar^{20}$  and  $Ar^{30}$  are as defined above, with an activated carboxylic acid derivative of formula VII as defined above in the presence of a tertiary amine base such as triethylamine, tributylamine or diethylisopropylamine in an inert solvent such as  $CH_2Cl_2$ . Again, as in the case of Method A, protecting groups at  $Ar^{10}$ ,  $Ar^{20}$ ,  $Ar^{30}$ ,  $R^1$  and  $R^2$  are removed as necessary. Use of other bases, e.g., pyridine, favors formation of compounds of formula Ib.

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#### Method E:

[0040]

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[0041] In the first step, compound XII is dissolved in a suitable solvent, e.g., anhydrous  $CH_2Cl_2$ , and treated with a Lewis acid, e.g.,  $TiCl_4$  at about  $-60^\circ C$  to  $0^\circ C$ , preferably at about  $-25^\circ C$ , under a dry, inert atmosphere, e.g., argon. A tertiary amine base such as TMEDA is added and the mixture stirred at about  $-60^\circ C$  to  $0^\circ C$ , preferably at about  $-25^\circ C$  to  $-15^\circ C$ , for a period of about 1 h. An imine of formula  $Ar^{30}CH=NAr^{20}$  is added neat or optionally as a solution in a suitable solvent, e.g. anhydrous  $CH_2Cl_2$ , over a period of about 5 min, and the reaction is stirred vigorously at about  $-60^\circ C$  to  $0^\circ C$ , preferably at about  $-25^\circ C$  to  $-15^\circ C$ , for about 3 to 6 h, preferably about 4 h or until the reaction is complete by TLC. An acid, e.g. acetic acid, is added to reaction at the reaction temperature and the mixture is allowed to warm to room temperature slowly with stirring for about 1-3 hours, preferably about 2 hours. The compound of formula XIII is isolated by extraction with a suitable solvent, e.g.  $CH_2Cl_2$ , then purified by crystallization or silica gel chromatography.

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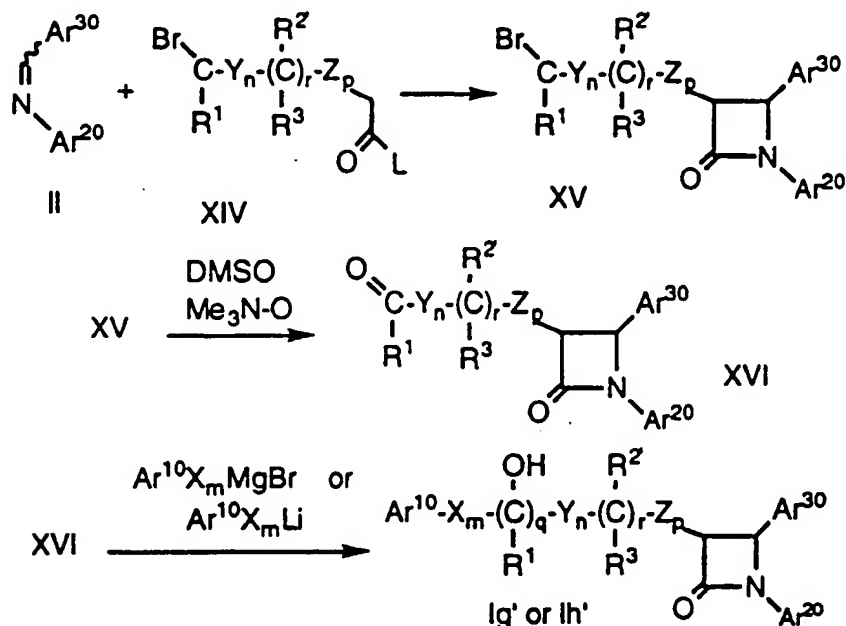
[0042] In the second step, the product is treated with a strong non-nucleophilic base, such as sodium or lithium



bis(trimethylsilyl)amide at about -78°C to 10°C. After reaction, the mixture is poured into aqueous tartaric acid and the product isolated from the organic layer. As in the case of Method A, protecting groups at Ar<sup>10</sup>, Ar<sup>20</sup>, Ar<sup>30</sup>, R<sup>1</sup> and R<sup>2</sup> are removed as necessary. This process, including the preparation of the starting material of formula XII, is also described in greater detail in WO93/02048.

#### Method F:

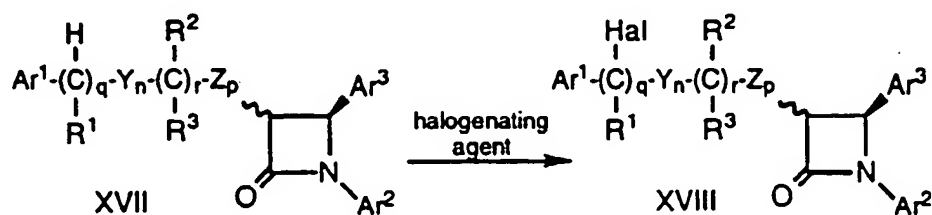
[0043]

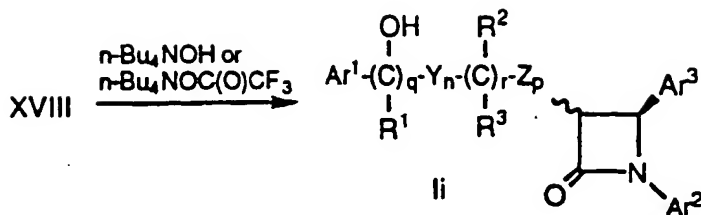


Compounds of formula Ig' and Ih' (i.e., compounds of formula I wherein R is OH), wherein R<sup>2</sup> is a protected hydroxy group as defined above, and the remaining variables are as defined above, can be prepared by reacting an imine of formula II and a carboxylic acid derivative of formula XIV, wherein the variables are as defined above, according to Method D, followed by oxidation of the resultant halide of formula XV by treatment with an oxidizing agent such as trimethylamine oxide, CrO<sub>3</sub> or ozone in a solvent such as DMSO. The resultant aldehyde or ketone of formula XVI is then reacted with an aryl organometallic reagent (e.g., Ar<sup>10</sup>X<sub>m</sub>MgBr, Ar<sup>10</sup>X<sub>m</sub>Li, Ar<sup>10</sup>X<sub>m</sub>MgCl or Ar<sup>10</sup>X<sub>m</sub>CeCl<sub>2</sub>) to obtain a compound of formula Ig' or Ih'. As described above, the Ar<sup>10</sup>, Ar<sup>20</sup>, Ar<sup>30</sup> and R<sup>2</sup> substituents can be converted to the desired Ar<sup>1</sup>, Ar<sup>2</sup>, Ar<sup>3</sup> and R<sup>2</sup> substituents by procedures well known in the art.

#### Method G:

[0044]

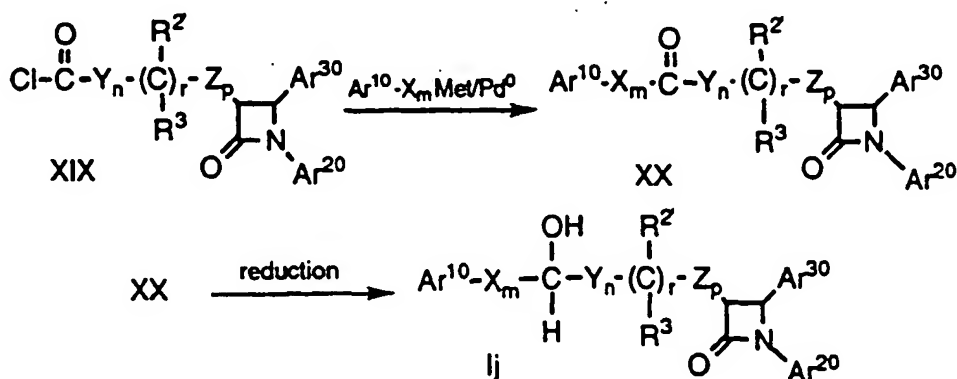




Compounds of formula II having a hydroxy substituent on the side chain adjacent to the Ar<sup>1</sup> group (i.e., compounds of formula I wherein m is 0) can be prepared by heating a compound of formula XVII, prepared by Method D, above, wherein the variables are as defined above, for about 1-6 hours at about 60°C to 100°C with a halogenating agent such as N-bromosuccinimide (NBS) in a suitable solvent such as CCl<sub>4</sub> in the presence of an initiating agent such as benzoyl peroxide. The resultant compound of formula XVIII, wherein Hal is Cl, Br or I and the remaining variables are as defined above, is then heated in a suitable solvent such as CH<sub>2</sub>Cl<sub>2</sub> with a tetraalkyl-ammonium salt such as tetra n-butylammonium hydroxide (n-Bu<sub>4</sub>NOH) to obtain the compound of formula II. Alternatively, compound XVIII can be heated in a suitable solvent such as CH<sub>2</sub>Cl<sub>2</sub> with tetra n-butylammonium trifluoroacetate (n-Bu<sub>4</sub>NOC(O)CF<sub>3</sub>) followed by treatment with a mild base such as ethanol saturated with NH<sub>3</sub> to obtain compound II.

#### Method H:

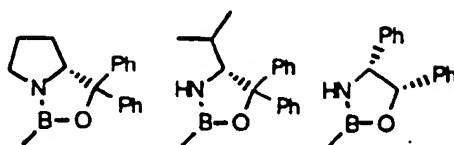
[0045]



[0046] Compounds of formula Ij (i.e., compounds of formula I wherein R is OH, R<sup>1</sup> is H and q is 1) are prepared from compound XIX in 2 steps. First, a compound of formula XIX, wherein the variables are as defined above, is dissolved in a suitable anhydrous solvent, e.g. THF, at about -20°C to about 22°C, preferably at about 0°C under a dry inert atmosphere, e.g. argon and adding a transition metal source, e.g. tetrakis(triphenylphosphine)-palladium or palladium acetate/ triphenyl phosphine. An organometallic of formula Ar<sup>10</sup>-X<sub>m</sub>-Met, wherein Ar<sup>10</sup>, X and m are as defined above and Met is, for example, ZnCl or B(OH)<sub>2</sub>, is added to the reaction mixture at about -20°C to about 22°C, preferably at about 0°C, the reaction mixture is stirred for about 15 min to 4 h, preferably about 1 h, and is then allowed to warm to about 22°C. Addition of dilute acid, e.g. 1N HCl, followed by extraction with a suitable organic solvent, e.g. ethyl acetate (EtOAc), produces compound XX.

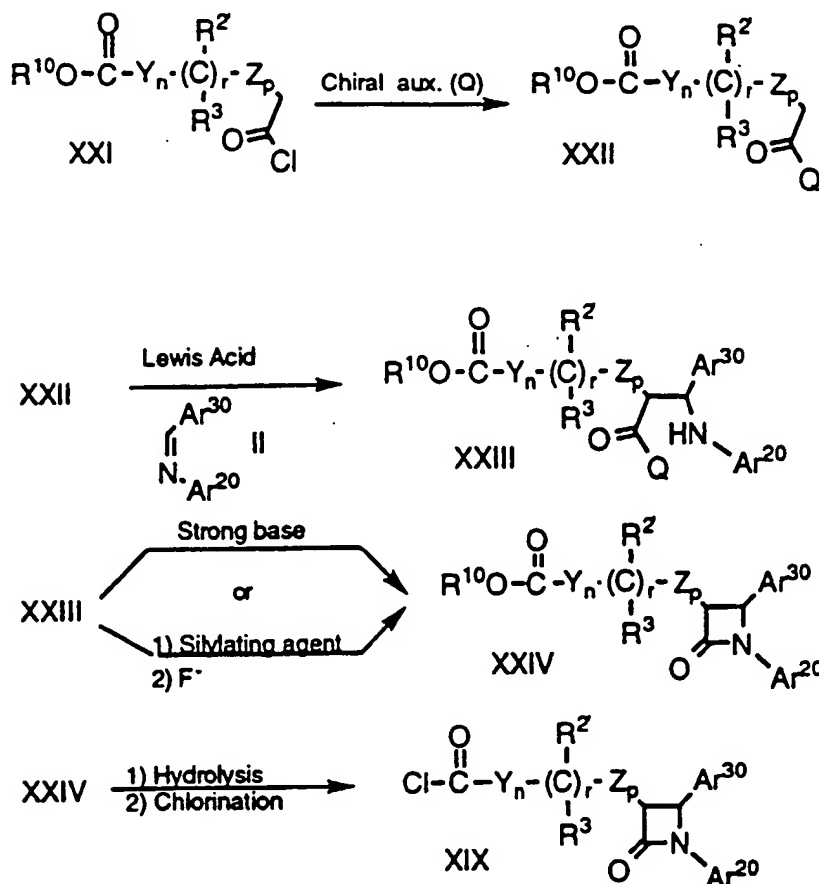
[0047] The ketone of formula XX is dissolved in a suitable solvent, e.g. CH<sub>3</sub>OH, a hydrogenation catalyst is added, e.g. Pd on carbon, and the mixture is exposed to H<sub>2</sub> gas under a pressure of about 14 psi to 100 psi, preferably about 60 psi for about 1 to 24 h, preferably about 16 h. The hydrogenation catalyst is removed by filtration and the solvent is removed in vacuo to produce a compound Ij as a mixture of alcohol diastereomers which can be separated by conventional means.

[0048] Alternatively, a ketone of formula XX is dissolved in a suitable solvent, e.g. THF, at about -40°C to about 22°C, preferably at about 0°C, and a suitable reducing agent such as NaBH<sub>4</sub>, a substituted borohydride (e.g., [cbz-proline]<sub>2</sub>BHNa) or a borane is added, optionally in the presence of a suitable chiral promotor present either in catalytic or stoichiometric amounts, e.g., chiral borane of structures:



Addition of dilute acid, e.g., 1N HCl, followed by extraction with a suitable solvent produces compounds of formula Ij. As above, protecting groups at Ar<sup>10</sup>, Ar<sup>20</sup>, Ar<sup>30</sup> and R<sup>2</sup> are removed as necessary. When either a chiral reagent or a chiral promotor is used, the resulting product is non-racemic.

[0049] Compounds of formula XIX can be prepared by a multi-step procedure as represented below:



Compounds of formula XXI, wherein R<sup>10</sup> is lower alkyl and the remaining variables are as defined above, are commercially available or can be prepared by treating the corresponding carboxylic acid (i.e., compounds wherein the Cl is replaced by a hydroxy group) with a chlorinating agent, e.g. SOCl<sub>2</sub> or oxalyl chloride, under a dry atmosphere, neat or in a suitable inert organic solvent, e.g. toluene at about 40°C to 110°C, preferably about 70°C; alternatively, a catalyst made be added, e.g. dimethylformamide (DMF), the reaction is conducted at about 22°C and the solvent and excess reagents are removed in vacuo. The compound XXI is reacted with a chiral auxiliary such as (S)-4-phenyl-2-oxazolidinone according to the following procedure: a chiral auxiliary is treated with a strong base such as an alkyl lithium, a metal hydride or a tertiary amine base such as triethylamine, in a suitable anhydrous organic solvent, e.g., dry THF, under a dry, inert atmosphere, e.g. argon, at about -85°C to 22°C, preferably about 0°C, for about 10 min to 60 min, preferably about 30 minutes. The resulting anion is reacted, without isolation, with compound XXI in a suitable anhydrous organic solvent, e.g. dry THF, under a dry, inert atmosphere, e.g. argon, at about -85°C to about 22°C, preferably 0°C, for about 30 min to 60 min, preferably 30 min. The reaction is warmed to about 22°C and continued for 1 to 12 h, preferably 6 h. Water is added and compound XXII is isolated by extraction and purified by crystallization.

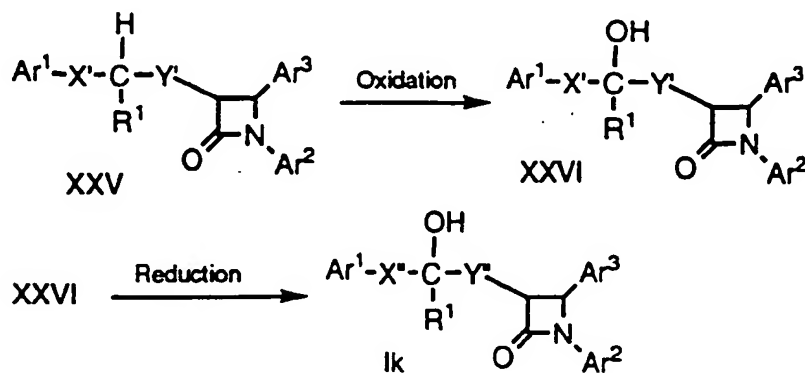
[0050] The compound of formula XXII is treated in the same manner as described in step 1 of Method E to obtain a compound XXIII.

[0051] Azetidinone ring closure can be accomplished by alternative procedures. By one method, a compound of formula XXIII is treated with a strong non-nucleophilic base, such as sodium or lithium-bis(trimethylsilyl)amide, in a suitable inert organic solvent, e.g.  $\text{CH}_2\text{Cl}_2$ , at about  $-78^\circ\text{C}$  to about  $10^\circ\text{C}$ , preferably about  $0^\circ\text{C}$ . The mixture is stirred for about 1 to 2 hours while gradually warming to about  $22^\circ\text{C}$ . Compound XXIV is isolated by conventional extraction with  $\text{CH}_2\text{Cl}_2$ . In another, two-step method, a compound of formula XXIII is first treated with mild silylating agent, e.g. N,O-bis(trimethylsilyl)acetamide at about  $0^\circ\text{C}$  to about  $100^\circ\text{C}$ , preferably about  $40^\circ\text{C}$  for about 10 min to 60 min, preferably 30 min, then treated with a fluoride anion source, e.g. tetrabutylammonium fluoride (TBAF), at about  $0^\circ\text{C}$  to about  $100^\circ\text{C}$ , preferably  $40^\circ\text{C}$ , and allowed to stir for about 0.5 to about 4 hours, preferably about 2 hours. Compound XXIV is isolated by conventional extraction methods.

[0052] The compound of formula XXIV is hydrolysed by a suitable base, e.g.  $\text{LiOH}$ , in a suitable solvent, e.g. 66%  $\text{CH}_3\text{OH}/\text{water}$  at about  $0^\circ\text{C}$  to about  $50^\circ\text{C}$ , preferably  $22^\circ\text{C}$ , for about 1 to 4 hours, preferably 2 hours, then extracted with a suitable solvent, e.g.  $\text{EtOAc}$ . The resulting acid is converted to the acid chloride as described above by treatment with a chlorination agent, e.g. oxalyl chloride, to afford compound XIX.

#### Method I:

[0053]



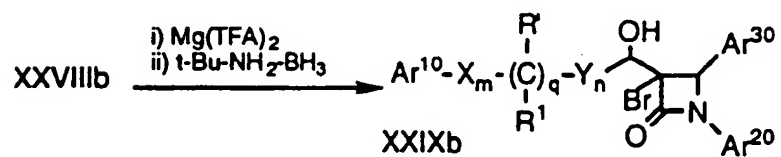
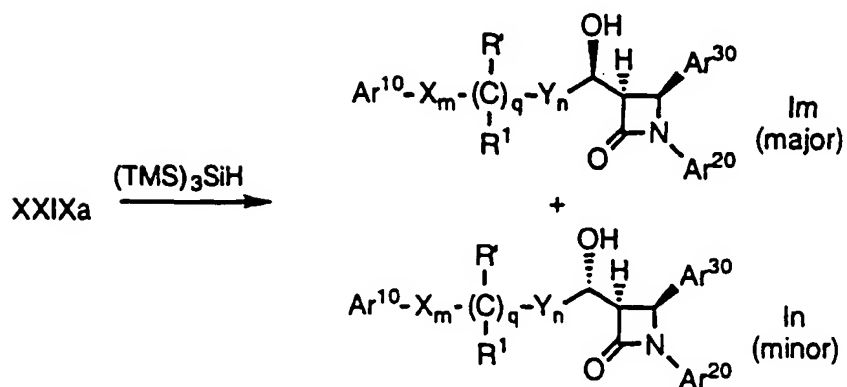
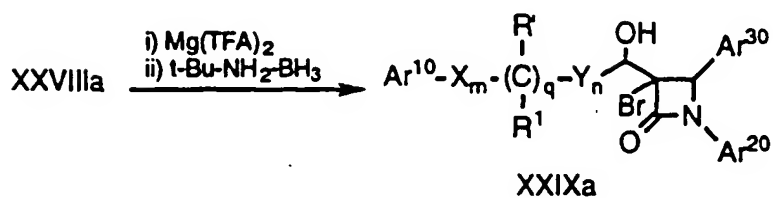
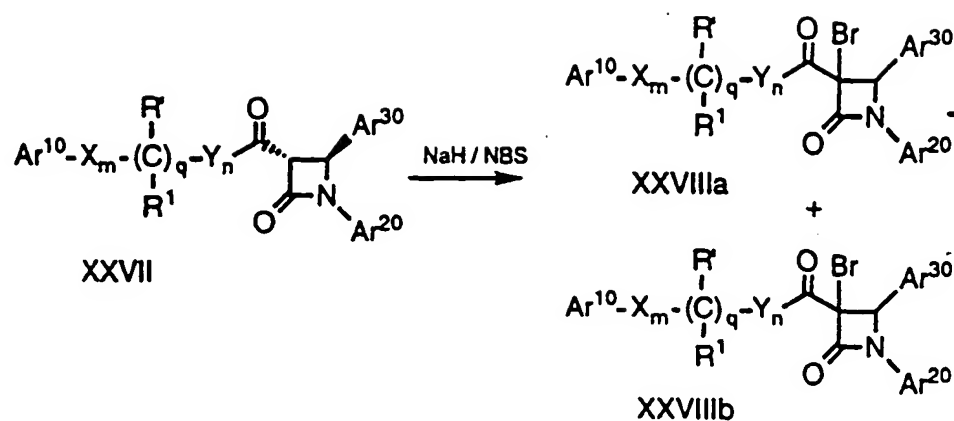
[0054] Compounds of formula I k, wherein  $\text{Ar}^1$ ,  $\text{Ar}^2$ ,  $\text{Ar}^3$  and  $\text{R}^1$  are as defined above, one of  $\text{X}^*$  and  $\text{Y}^*$  is  $-\text{CH}_2\text{CH}_2-$  and the other is selected from the group consisting of  $-\text{CH}_2\text{CH}_2-$ ,  $-\text{CH}_2-$ ,  $-\text{CH}(\text{lower alkyl})-$ ,  $-\text{CH}(\text{dilower alkyl})-$  and a bond, are prepared by oxidation of an alkene of formula XXV, wherein one of  $\text{X}^*$  and  $\text{Y}^*$  is  $-\text{CH}=\text{CH}-$  and the other is  $-\text{CH}=\text{CH}-$ ,  $-\text{CH}_2-$ ,  $-\text{CH}_2\text{CH}_2-$ ,  $-\text{CH}(\text{lower alkyl})-$ ,  $-\text{CH}(\text{dilower alkyl})-$  or a bond, and the remaining variables are as defined above, can be prepared by the following two step procedure.

[0055] A compound of formula XXV, which can be prepared by Method D, above, is treated with an oxidizing agent such as  $\text{SeO}_2$ , phenylselenic anhydride or  $\text{CrO}_3$  in a suitable solvent such as dioxane at about  $22^\circ$  to  $100^\circ\text{C}$  for about 0.5 to 12 hours. After the starting material is consumed as determined by TLC, or 12 hours, the reaction is cooled to about  $22^\circ\text{C}$  and the product XXVI is isolated by extraction.

[0056] In the second step, an allylic alcohol of formula XXVI is dissolved in a suitable solvent, e.g.,  $\text{EtOAc}$ , a hydrogenation catalyst is added, e.g., Pd on carbon, and the mixture is exposed to  $\text{H}_2$  gas under a pressure of about 14 psi to 60 psi for about 1 to 12 hours. The hydrogenation catalyst is removed in vacuo to obtain a compound of formula I k.

Method J:

[0057]



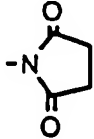
Alcohols of formula Im and In (i. ., compounds of formula I wherein r is 1, R<sup>2</sup> is -OH, R<sup>3</sup> is hydrogen and p is 0) can

be selectively obtained from ketones of formula XXVII in three steps comprising bromination, reduction and debromination. Since the stereochemistry of the major isomers of alcohols XXIXa and XXIXb are different, one can selectively prepare either diastereomeric alcohol.

[0058] In the above process, a ketone of formula XXVII, which can be prepared by oxidation of the corresponding hydroxy compound by well known methods, is halogenated, for example by treatment in an inert solvent, e.g., THF, with NaH followed by N-bromosuccinimide, to obtain a mixture of 3-bromo-ketone compounds XXVIII (a and b). Compounds XXVIIIa and XXVIIIb are then separately reduced to the corresponding alcohols, for example by treatment with magnesium trifluoroacetate ( $Mg(TFA)_2$ ) and t-butylamine borane ( $t\text{-Bu-NH}_2\text{-BH}_3$ ) in an inert solvent such as THF at a temperature of about  $-78^\circ\text{C}$  to  $0^\circ\text{C}$ . The resultant alcohols XXIX are dehalogenated by treatment with tris(trimethylsilyl)silane ( $(TMS)_3SiH$ ) in a solvent such as toluene in the presence of a radical initiator such as 2,2'-azobisisobutyronitrile (AIBN) to obtain a mixture of isomers Im and In which can be separated into individual enantiomers by conventional means, e.g., HPLC. Again, protecting groups at  $Ar^{10}$ ,  $Ar^{20}$ ,  $Ar^{30}$  and R' are removed as necessary.

[0059] Starting compounds III, V, VI, VII, VIII, XIV, XVII, XXI and XXV are all either commercially available or well known in the art and can be prepared via known methods.

[0060] Reactive groups not involved in the above processes can be protected during the reactions with conventional protecting groups which can be removed by standard procedures after the reaction. The following Table 1 shows some typical protecting groups:

Group to be Protected	Table 1 Group to be Protected and Protecting Group
-COOH	-COOalkyl, -COObenzyl, -COOphenyl
$>NH$	$>NCOalkyl$ , $>NCObenzyl$ , $>NCOphenyl$ $>NCH_2OCH_2CH_2Si(CH_3)_3$ , $>NC(O)OC(CH_3)_3$ , $>N\text{-benzyl}$ , $>NSi(CH_3)_3$ , $>NSi(CH_3)_2C(CH_3)_3$
-NH <sub>2</sub>	
-OH	$-OCH_3$ , $-OCH_2OCH_3$ , $-OSi(CH_3)_2C(CH_3)_3$ , $-OSi(CH_3)_3$ , or $-OCH_2phenyl$

[0061] We have found that the compounds of this invention lower serum lipid levels, in particular serum cholesterol levels. Compounds of this invention have been found to inhibit the intestinal absorption of cholesterol and to significantly reduce the formation of liver cholesteryl esters in animal models. Thus, compounds of this invention are hypocholesterolemic agents by virtue of their ability to inhibit the intestinal absorption and/or esterification of cholesterol; they are, therefore, useful in the treatment and prevention of atherosclerosis in mammals, in particular in humans.

[0062] The *in vivo* activity of the compounds of formula I can be determined by the following procedure:

#### 55 In Vivo Assay of Hypolipidemic Agents Using the Hyperlipidemic Hamster

[0063] Hamsters are separated into groups of six and given a controlled cholesterol diet (Purina Chow #5001 containing 0.5% cholesterol) for seven days. Diet consumption is monitored to determine dietary cholesterol exposure in

the face of test compounds. The animals are dosed with the test compound once daily beginning with the initiation of diet. Dosing is by oral gavage of 0.2mL of corn oil alone (control group) or solution (or suspension) of test compound in corn oil. All animals moribund or in poor physical condition are euthanized. After seven days, the animals are anesthetized by intramuscular (IM) injection of ketamine and sacrificed by decapitation. Blood is collected into vacutainer tubes containing EDTA for plasma lipid analysis and the liver excised for tissue lipid analysis. Lipid analysis is conducted as per published procedures (Schnitzer-Polokoff, R., et al, *Comp. Biochem. Physiol.*, 99A, 4 (1991), p. 665-670) and data is reported as percent reduction of lipid versus control.

[0064] The present invention also relates to a pharmaceutical composition comprising a compound of formula I and a pharmaceutically acceptable carrier. The compounds of formula I can be administered in any conventional dosage form, preferably an oral dosage form such as a capsule, tablet, powder, cachet, suspension or solution. The formulations and pharmaceutical compositions can be prepared using conventional pharmaceutically acceptable excipients and additives and conventional techniques. Such pharmaceutically acceptable excipients and additives include non-toxic compatible fillers, binders, disintegrants, buffers, preservatives, anti-oxidants, lubricants, flavorings, thickeners, coloring agents, emulsifiers and the like.

[0065] The daily hypocholesteremic dose of a compound of formula I is about 0.1 to about 30 mg/kg of body weight per day, preferably about 0.1 to about 15 mg/kg. For an average body weight of 70 kg, the dosage level is therefore from about 5 mg to about 1000 mg of drug per day, given in a single dose or 2-4 divided doses. The exact dose, however, is determined by the attending clinician and is dependent on the potency of the compound administered, the age, weight, condition and response of the patient.

[0066] For the combinations of this invention wherein the hydroxy substituted azetidinone is administered in combination with a cholesterol biosynthesis inhibitor, the typical daily dose of the cholesterol biosynthesis inhibitor is 0.1 to 80 mg/kg of mammalian weight per day administered in single or divided dosages, usually once or twice a day: for example, for HMG CoA reductase inhibitors, about 10 to about 40 mg per dose is given 1 to 2 times a day, giving a total daily dose of about 10 to 80 mg per day, and for the other cholesterol biosynthesis inhibitors, about 1 to 1000 mg per dose is given 1 to 2 times a day, giving a total daily dose of about 1 mg to about 2000 mg per day. The exact dose of any component of the combination to be administered is determined by the attending clinician and is dependent on the potency of the compound administered, the age, weight, condition and response of the patient.

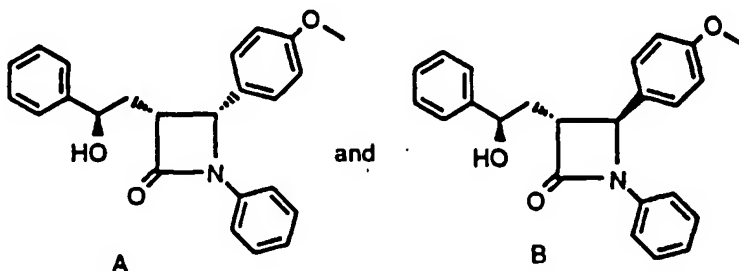
[0067] Where the components of a combination are administered separately, the number of doses of each component given per day may not necessarily be the same, e.g. where one component may have a greater duration of activity, and will therefore need to be administered less frequently.

[0068] Since the present invention relates to the reduction of plasma cholesterol levels by treatment with a combination of active ingredients wherein said active ingredients may be administered separately, the invention also relates to combining separate pharmaceutical compositions in kit form. That is, a kit is contemplated wherein two separate units are combined: a cholesterol biosynthesis inhibitor pharmaceutical composition and a hydroxy substituted azetidinone cholesterol absorption inhibitor pharmaceutical composition. The kit will preferably include directions for the administration of the separate components. The kit form is particularly advantageous when the separate components must be administered in different dosage forms (e.g. oral and parenteral) or are administered at different dosage intervals.

[0069] Following are examples of preparing compounds of formula I. The stereochemistry listed is relative stereochemistry unless otherwise noted. The terms cis and trans refer to the relative orientations at the azetidinone 3- and 4-positions unless otherwise indicated. The term "J" refers to the proton NMR coupling constant in hertz (Hz) between the 3-and 4-substituted protons of the azetidinone. All NMR data is of CDCl<sub>3</sub> solution unless otherwise indicated.

#### EXAMPLE 1

[0070]

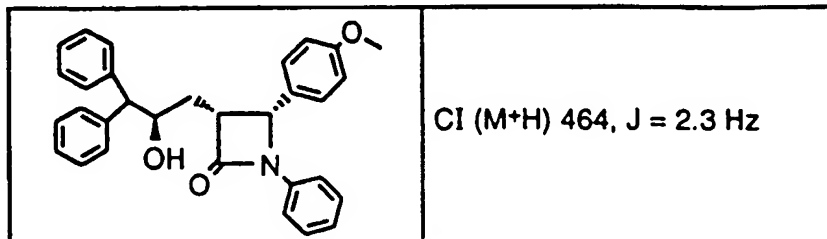


[0071] Freshly prepare a solution of lithium diisopropylamide (LDA) by dissolving diisopropylamine (1.19 g, 11.8 mmol) in anhydrous THF (20 ml) at -78°C under argon. Add n-butyllithium (4.9 ml, 11.8 mmol, 2.4M in hexanes) and stir for 0.5 h at -78°C. To this cold solution add, 4-phenyl-butyrolactone (1.75 g, 10.8 mmol) in THF (4 ml) over 0.25 h, keeping the reaction temperature below -65°C. Stir at -78°C for 0.25 h, then add 4-methoxybenzylidene anisidine (2.33 g, 11.0 mmol) in THF (8 ml) over 1 h at -78°C. Warm the reaction slowly to -50°C over 1 h. Quench the reaction at low temperature with 1N HCl (12 ml). Partition the reaction mixture between ether and 1N HCl, wash the ether layer with water, combine the ether extracts, dry over MgSO<sub>4</sub> and concentrate in vacuo. Crystallize the crude reaction residue (3.0 g) from EtOAc-ether to obtain 1.54 g of compound A. Reconcentrate the filtrate and chromatograph on silica gel 60, eluting with 4:1 EtOAc-hexane, and isolate additional compound A (0.385 g) as well as compound B (0.420 g).

[0072] Compound A: mp 218-220°C; IR 1730 cm<sup>-1</sup>; CI (M+H) 374; J = 5.9 Hz.

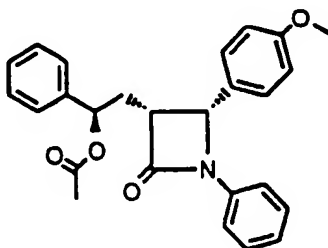
[0073] Compound B: mp 74-76°C; IR 1730 cm<sup>-1</sup>; CI (M+H) 374; J = 2.3 Hz.

[0074] Using a similar procedure and appropriate starting materials, prepare compound 1C:



## EXAMPLE 2

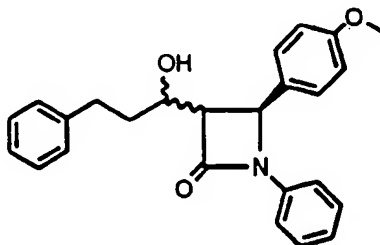
[0075]



[0076] To a solution of compound A from Example 1 (0.5 g, 1.3 mmol) in anhydrous pyridine (2.7 ml), add acetic anhydride (0.63 ml, 6.7 mmol). Stir for 16 h, dilute with CH<sub>2</sub>Cl<sub>2</sub> and wash 3x with 1N HCl, 1x with NaCl (sat'd) and 1x with water. Concentrate the organic layer to dryness and crystallize the residue from EtOAc to obtain the title compound (0.46 g), mp 167-169°C; IR 1745 cm<sup>-1</sup>; EI (M+) 415; J = 5.9 Hz.

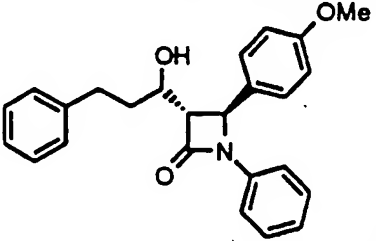
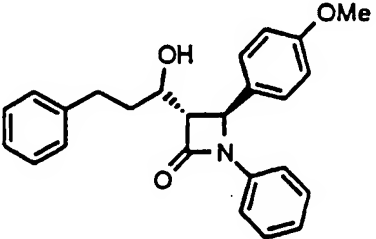
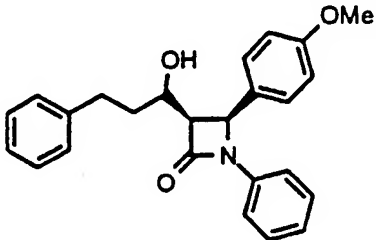
## EXAMPLE 3

[0077]

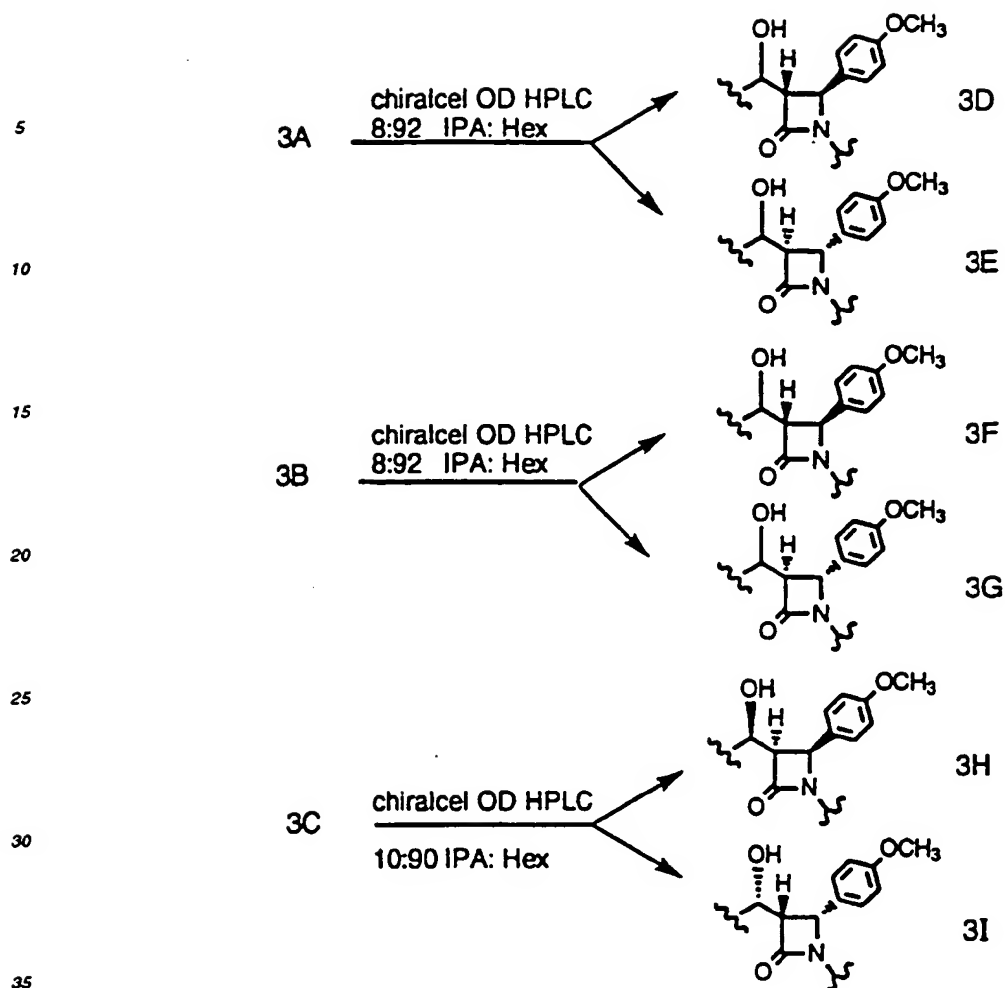




[0078] Freshly prepare a solution of lithium isopropylcyclohexylamide (LICA) by adding n-butyllithium (2.84 mL of a 1.6M solution) to a solution of isopropylcyclohexylamine (0.75 mL) in THF (100 mL) at -78°C. Dissolve N-phenyl-4-(4-methoxyphenyl)-2-azetidinone (1.0 g) in THF (8 mL) and slowly add to the LICA solution at -78°C. After stirring for 20 min, add hydrocinnamaldehyde (0.54 g) and stir the reaction mixture at -78°C for 4 h. Quench the reaction with 10% KHSO<sub>4</sub> and extract the product with EtOAc. Separate the organic layer, wash with water and NaCl (sat'd). Concentrate the extract and purify the resultant residue on a silica gel 60 column, eluting with EtOAc:hexane (15:85) to obtain 1.15 g of product as a mixture of diastereomers. Separate the diastereomers by HPLC on a silica gel column to give three diastereomers 3A, 3B and 3C:

 <p>3A</p>	<p>1H in CDCl<sub>3</sub>: 7.32-7.18 (m, 11H); 7.08-6.99 (m, 1H); 6.89 (d, J=9 Hz, 2H); 4.80 (d, J=2.4 Hz, 1H); 4.10-4.00 (m, 1H); 3.79 (s, 3H); 3.20-3.16 (m, 1H); 2.90-2.67 (m, 2H); 2.15-1.85 (m, 3H)</p>
 <p>3B</p>	<p>1H in CDCl<sub>3</sub>: 7.35-7.10 (m, 11H); 7.08-6.99 (m, 1H); 6.89 (d, J=9 Hz, 2H); 5.09 (d, J=2.4 Hz, 1H); 4.26-4.14 (m, 1H); 3.79 (s, 3H); 3.21-3.14 (m, 1H); 2.89-2.57 (m, 2H); 2.10-1.85 (m, 3H)</p>
 <p>3C</p>	<p>1H in CDCl<sub>3</sub>: 7.30-7.00 (m, 10H); 6.99 (d, J=8 Hz, 2H); 6.83 (d, J=9 Hz, 2H); 5.12 (d, J=5.5 Hz, 1H); 3.82 (s, 3H); 3.75-3.63 (m, 1H); 3.52 (dd, J=9.5 Hz, 1H); 2.71-2.57 (m, 1H); 2.49-2.33 (m, 1H); 1.68-1.50 (m, 1H); 1.47-1.31 (m, 1H)</p>

The 3A, 3B and 3C diastereomers were further separated according to the following reaction scheme, wherein partial structures are shown:



(The following CD spectra data  $[\theta]$  are all obtained in  $\text{CH}_3\text{OH}$ .)

[0079] 3D)  $[\theta]_{227\text{nm}} = +2.0 \times 10^4 \text{ cm}^2/\text{dM}$ ;  $[\theta]_{241\text{nm}} = -4.6 \times 10^4 \text{ cm}^2/\text{dM}$ . Elemental analysis calc for  $\text{C}_{25}\text{H}_{25}\text{NO}_3 \cdot 0.25 \text{ H}_2\text{O}$ : C 76.6; H 6.56; N 3.57. found: C 76.66; H 6.49; N 3.64.

[0080] 3E)  $[\theta]_{227\text{nm}} = -1.95 \times 10^4 \text{ cm}^2/\text{dM}$ ;  $[\theta]_{241\text{nm}} = +4.45 \times 10^4 \text{ cm}^2/\text{dM}$ . Elemental analysis calc for  $\text{C}_{25}\text{H}_{25}\text{NO}_3 \cdot 0.5 \text{ H}_2\text{O}$ : C 75.73; H 6.61; N 3.53. found: C 75.66; H 6.41; N 3.60.

[0081] 3F)  $[\theta]_{226\text{nm}} = +1.97 \times 10^4 \text{ cm}^2/\text{dM}$ ;  $[\theta]_{240\text{nm}} = -5.22 \times 10^4 \text{ cm}^2/\text{dM}$ . Elemental analysis calc for  $\text{C}_{25}\text{H}_{25}\text{NO}_3$ : C 77.48; H 6.51; N 3.62. found: C 77.44; H 6.53; N 3.70.

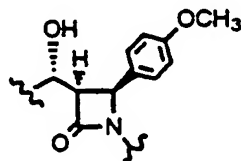
[0082] 3G)  $[\theta]_{226\text{nm}} = -1.78 \times 10^4 \text{ cm}^2/\text{dM}$ ;  $[\theta]_{241\text{nm}} = +4.78 \times 10^4 \text{ cm}^2/\text{dM}$  (CIMS 388  $\text{M}^+\text{H}$ ).

[0083] 3H)  $[\theta]_{226\text{nm}} = +2.24 \times 10^4 \text{ cm}^2/\text{dM}$ ;  $[\theta]_{241\text{nm}} = -5.4 \times 10^4 \text{ cm}^2/\text{dM}$ .  $[\alpha]_{\text{D}}^{25} = -54.4^\circ$  (2.5 mg/ml  $\text{CH}_3\text{OH}$ )  
Elemental analysis calc for  $\text{C}_{25}\text{H}_{25}\text{NO}_3$ : C 77.48; H 6.51; N 3.62. found: C 77.11; H 6.50; N 3.72.

[0084] 3I)  $[\theta]_{226\text{nm}} = -2.05 \times 10^4 \text{ cm}^2/\text{dM}$ ;  $[\theta]_{241\text{nm}} = +5.2 \times 10^4 \text{ cm}^2/\text{dM}$ . (CIMS 388  $\text{M}^+\text{H}$ ).

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3J)

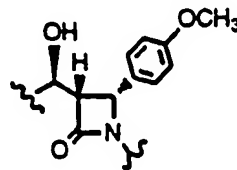


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[0085] Add DEAD (0.11 ml) to a solution of compound 3H (132 mg),  $\text{PPh}_3$  (0.18 g) and  $\text{HCO}_2\text{H}$  (39 ml) in THF (5 ml). Stir at room temperature overnight, then partition the reaction mixture between  $\text{Et}_2\text{O}$  and  $\text{H}_2\text{O}$ . Wash (brine) and

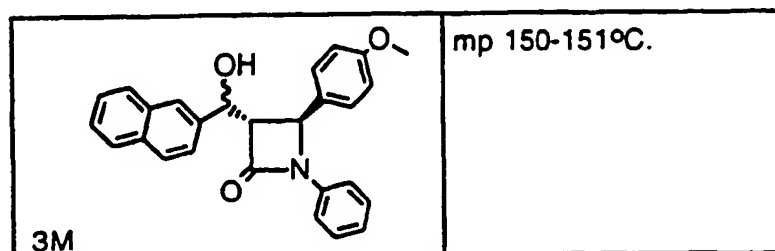
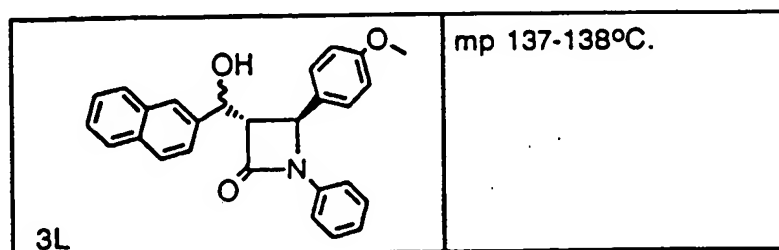
dry (MgSO<sub>4</sub>) the organic layer and concentrate to dryness. Flash chromatograph the residue using EtOAc:Hex (1:4) to obtain the formate ester. Dissolve this in CH<sub>3</sub>OH and add 4 drops of conc. HCl. After 4 h, concentrate in vacuo and flash chromatograph the residue using EtOAc:Hex (1:3) to obtain 3J.  $[\theta]_{224\text{nm}} = +2.54 \times 10^3 \text{ cm}^2/\text{dM}$ ;  $[\theta]_{239\text{nm}} = +5.70 \times 10^4 \text{ cm}^2/\text{dM}$ .  $[\alpha]_{\text{D}}^{20} = -157.6^\circ$  (2.5 mg/ml CH<sub>3</sub>OH).

3K)



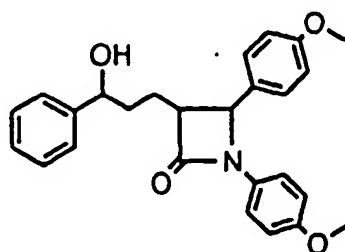
[0086] Using the procedure described for 3J, treat compound 3I to obtain 3K.  $[\theta]_{222\text{nm}} = -3.4 \times 10^3 \text{ cm}^2/\text{dM}$ ;  $[\theta]_{240\text{nm}} = -5.6 \times 10^4 \text{ cm}^2/\text{dM}$ .  $[\alpha]_{\text{D}}^{20} = +167.2^\circ$  (2.5 mg/ml CH<sub>3</sub>OH).

[0087] Using the procedure described above for preparing compounds 3A and 3B, treat N-phenyl-4-(4-methoxyphenyl)-2-azetidinone with LICA followed by 2-naphthaldehyde to obtain the diastereomers 3L and 3M:



#### EXAMPLE 4

[0088]



Method 1:

- 5 [0089] Step 1) To a refluxing solution of 4-methoxybenzyliden anisidine (10.0 g, 41.5 mmol) and tributylamine (20.8 ml, 87 mmol) in toluene (100 ml), add 5-bromovaleroyl chloride (8.5 g, 43 mmol) in toluene (20 ml) dropwise over 2 h. Stir the reaction mixture at 80°C for 12 h, cool to room temperature, wash 3x with 1N HCl, 1x with water and dry the organic layer over MgSO<sub>4</sub>. Purify by silica gel chromatography, eluting with ethyl acetate:hexane (4:1) to obtain 5.1 g of (3R, 4S)-1,4-bis-(4-methoxyphenyl)-3-(3-bromopropyl)-2-azetidinone (relative stereochemistry), mp 70-73°C; EI (M<sup>+</sup>) 404; J = 2.3 Hz.
- 10 [0090] Step 2) To a solution of the product of step 1 (5.1 g, 12.6 mmol) in (CH<sub>3</sub>)<sub>2</sub>SO (20 ml), add (CH<sub>3</sub>)<sub>3</sub>M(O) (2.39 g, 31.9 mmol). Heat the mixture at 60°C for 3 h, cool to room temperature, dilute with EtOAc, and wash 3x with water. Combine the aqueous fractions and extract with EtOAc. Combine the organic fractions and concentrate. Purify the crude product by silica gel chromatography, eluting with EtOAc:hexane (1:1) to obtain 1.4 g (3R, 4S)-1,4-bis-(4-methoxyphenyl)-2-oxo-3-azetidine-propanal (relative stereochemistry), an oil; EI (M<sup>+</sup>) 339; J = 2.3 Hz.
- 15 [0091] Step 3) To a solution of the product of step 2 (0.734 g, 2.2 mmol) in THF (4 ml) at 0°C, add phenylmagnesium bromide (2.4 ml, 2.4 mmol, 1.0 M in THF) over 0.25 h. After 1 h at 0°C, add water (5 ml), separate the layers, wash the organic layer 1x with 1N HCl, dry with MgSO<sub>4</sub> and concentrate to an oil. Purify by silica gel chromatography, eluting with EtOAc:hexane (2:1) to obtain 0.372 g of the title compound (mix of diastereomers) as an oil. CI (M<sup>+</sup>H) 418.
- 20 [0092] Separation of diastereomers: Apply the diastereomeric mixture from step 3 to a Chiralcel OD (Chiral Technologies Corp, PA) chromatography column, eluting with hexane: ethanol (9:1) to obtain enantiomerically pure (>98%) diastereomers as follows:

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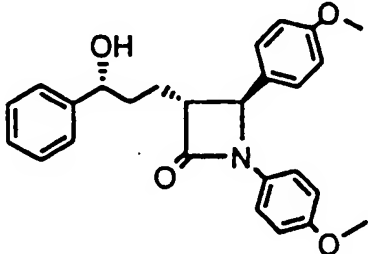
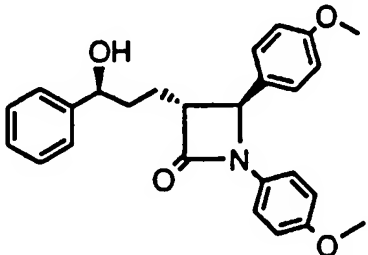
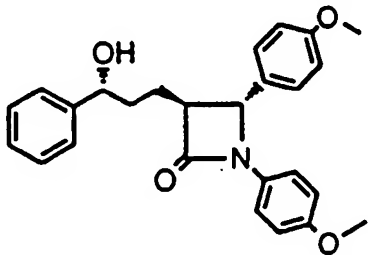
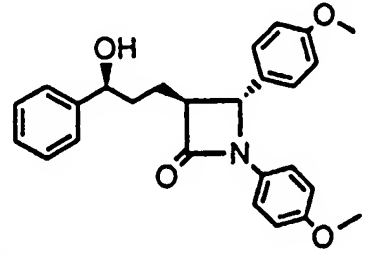
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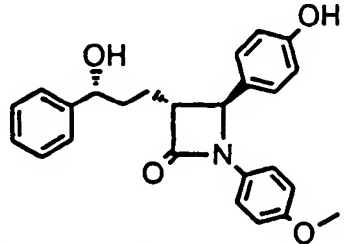
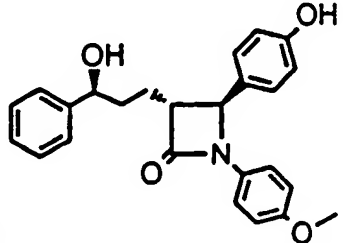
5		Oil; $[\alpha]_D^{22} = +8.3$ , conc.=3 mg/ml in MeOH; CI (M+H) 418. J = 2.1 Hz.
10	4A	
15		Oil; $[\alpha]_D^{22} = +33.1^\circ$ , conc.=3 mg/ml in MeOH; CI (M+H) 418. J = 2.1 HZ.
20	4B	
25		Oil; $[\alpha]_D^{22} = -8.0^\circ$ , conc.=3 mg/ml in MeOH; CI (M+H) 418. J = 2.1 Hz.
30	4C	
35		Oil; $[\alpha]_D^{22} = -29.5^\circ$ , conc.=3 mg/ml in MeOH; CI (M+H) 418. J = 2.1 Hz.
40	4D	

Method 2:

[0093] Step 1) To a solution of 1,4-(S)-bis(4-methoxyphenyl)-3-(3(R)-phenylpropyl)-2-azetidinone (5.04 g, 0.013 mole) in  $\text{CCl}_4$  (20 ml) at  $80^\circ\text{C}$ , add NBS (2.76 g, 0.0155 mole) and benzoyl peroxide (0.24 g, 1.0 mmole) in three equal portions over 1 h. Follow the reaction by TLC (4:1 hexane: EtOAc). Cool the reaction to  $22^\circ\text{C}$ , add  $\text{NaHSO}_4$ , separate the layers and wash the organic layer 3x with water. Concentrate the organic layer to obtain the crude product. CI (M+H) 480;  $^1\text{H}$  in  $\text{CDCl}_3$   $\delta$   $\text{PhCH}(\text{OH}) = 5.05$  ppm.

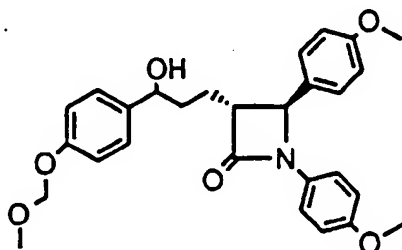
[0094] Step 2) Dissolve the crude product of Step 1 in  $\text{CH}_2\text{Cl}_2$  (30 ml) and add 40% n-BuNOC(O)CF<sub>3</sub> in water (30 ml). Reflux the biphasic reaction for 24 h, cool, separate the layers and wash the organic layer 6x with water. Concentrate the organic layer to dryness and immediately redissolve the residue in ethanol saturated with  $\text{NH}_3$  (10 ml). After 1 h, concentrate the reaction mixture and partially purify by silica gel chromatography. Further purify by HPLC to obtain a 1:1 mixture of compounds 4A and 4B. The mixture can be further purified on a Chiracel OD column to obtain 4A and 4B separately as characterized above.

[0095] Using the procedure described in Example 4, Method 2, with 4(S)-(4-acetoxyphenyl)-3(R)-(3-phenylpropyl)-1-(4-methoxy-phenyl)-2-azetidinone as the starting material, prepare the following compounds:

<p>5</p> <p>10</p> <p>4E</p> 	<p>mp 87-90°C; HRMS calc'd for C<sub>25</sub>H<sub>25</sub>NO<sub>4</sub> = 403.1797, found 403.1785; <sup>1</sup>H in CDCl<sub>3</sub> δ PhCH(OH) = 4.82 ppm.</p>
<p>15</p> <p>20</p> <p>4F</p> 	<p>HRMS calc'd for C<sub>25</sub>H<sub>25</sub>NO<sub>4</sub> = 403.1797, found 403.1787; <sup>1</sup>H in CDCl<sub>3</sub> δ PhCH(OH) = 4.78 ppm.</p>

**EXAMPLE 5**

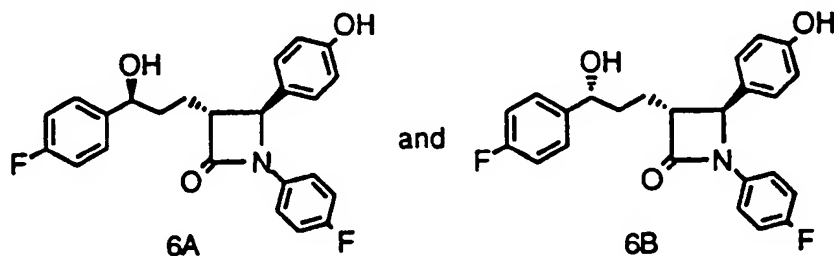
[0096]



[0097] To a solution of the product of step 2 of Example 4 (0.230 g, 0.68 mmol) in THF (2 ml), add the reagent derived from treatment of 4-methoxymethoxyphenyl bromide (0.159 g, 0.736 mmol) in THF (4 ml) at -78°C with sec-butyllithium (0.6 ml, 0.78 mol, 1.3 M in hexanes), followed by CeCl<sub>3</sub> (0.186 g, 0.75 mmol). After 4 h, extract the product and purify by chromatography in a manner similar to that described in step 3 of Example 4 to obtain 0.05 g of the title compound (mix of diastereomers) as an oil. CI (M<sup>+</sup>H) 478.

**EXAMPLE 6**

[0098]



[0099] Step 1): To a solution of (S)-4-phenyl-2-oxazolidinone (41 g, 0.25 mol) in CH<sub>2</sub>Cl<sub>2</sub> (200 ml), add 4-dimethyl-

aminopyridine (2.5 g, 0.02 mol) and triethylamine (84.7 ml, 0.61 mol) and cool the reaction to 0°C. Add methyl-4-(chloroformyl)butyrate (50 g, 0.3 mol) as a solution in CH<sub>2</sub>Cl<sub>2</sub> (375 ml) dropwise over 1 h, and allow the reaction to warm to 22°C. After 17 h, add water and H<sub>2</sub>SO<sub>4</sub> (2N, 100 ml), separate the layers, and wash the organic layer sequentially with NaOH (10%), NaCl (sat'd) and water. Dry the organic layer over MgSO<sub>4</sub> and concentrate to obtain a semi-crystalline product.

[0100] Step 2): To a solution of TiCl<sub>4</sub> (18.2 ml, 0.165 mol) in CH<sub>2</sub>Cl<sub>2</sub> (600 ml) at 0°C, add titanium isopropoxide (16.5 ml, 0.055 mol). After 15 min, add the product of Step 1 (49.0 g, 0.17 mol) as a solution in CH<sub>2</sub>Cl<sub>2</sub> (100 ml). After 5 min., add diisopropylethylamine (DIPEA) (65.2 ml, 0.37 mol) and stir at 0°C for 1 h, cool the reaction mixture to -20°C, and add 4-benzyloxybenzylidene(4-fluoro)aniline (114.3 g, 0.37 mol) as a solid. Stir the reaction vigorously for 4 h at -20°C, add acetic acid as a solution in CH<sub>2</sub>Cl<sub>2</sub> dropwise over 15 min, allow the reaction to warm to 0°C, and add H<sub>2</sub>SO<sub>4</sub> (2N). Stir the reaction an additional 1 h, separate the layers, wash with water, separate and dry the organic layer. Crystallize the crude product from ethanol/water to obtain the pure intermediate.

[0101] Step 3): To a solution of the product of Step 2 (8.9 g, 14.9 mmol) in toluene (100 ml) at 50°C, add N,O-bis(trimethylsilyl)acetamide (BSA) (7.50 ml, 30.3 mmol). After 0.5 h, add solid TBAF (0.39 g, 1.5 mmol) and stir the reaction at 50°C for an additional 3 h. Cool the reaction mixture to 22°C, add CH<sub>3</sub>OH (10 ml), wash the reaction mixture with HCl (1N), NaHCO<sub>3</sub> (1N) and NaCl (sat'd.), and dry the organic layer over MgSO<sub>4</sub>.

[0102] Step 4): To a solution of the product of Step 3 (0.94 g, 2.2 mmol) in CH<sub>3</sub>OH (3 ml), add water (1 ml) and LiOH·H<sub>2</sub>O (102 mg, 2.4 mmole). Stir the reaction at 22°C for 1 h and add additional LiOH·H<sub>2</sub>O (54 mg, 1.3 mmole). After a total of 2 h, add HCl (1N) and EtOAc, separate the layers, dry the organic layer and concentrate in vacuo. To a solution of the resultant product (0.91 g, 2.2 mmol) in CH<sub>2</sub>Cl<sub>2</sub> at 22°C, add ClCOCOCI (0.29 ml, 3.3 mmol) and stir for 16 h. Remove the solvent in vacuo.

[0103] Step 5): To an efficiently stirred suspension of 4-fluorophenylzinc chloride (4.4 mmol) prepared from 4-fluorophenylmagnesium bromide (1M in THF, 4.4 ml, 4.4 mmol) and ZnCl<sub>2</sub> (0.6 g, 4.4 mmol) at 4°C, add tetrakis(triphenylphosphine)palladium (0.25 g, 0.21 mmol) and the product of Step 4 (0.94 g, 2.2 mmol) as a solution in THF (2 ml). Stir the reaction for 1 h at 0°C and then for 0.5 h at 22°C. Add HCl (1N, 5 ml) and extract with EtOAc. Concentrate the organic layer to an oil and purify by silica gel chromatography to obtain 1-(4-fluorophenyl)-4(S)-[4-(phenyl-methoxy)phenyl]-3(R)-[3-oxo-3-(4-fluorophenyl)propyl]-2-azetidinone: HRMS calc'd for C<sub>24</sub>H<sub>19</sub>F<sub>2</sub>NO<sub>3</sub> = 408.1429, found 408.1411.

[0104] Step 6): To the product of Step 5 (0.95 g, 1.91 mmol) in THF (3 ml), add (R)-tetrahydro-1-methyl-3,3-diphenyl-1H,3H-pyrrolo-[1,2-c][1,3,2] oxazaborole (120 mg, 0.43 mmol) and cool the mixture to -20°C. After 5 min, add borohydride-dimethylsulfide complex (2M in THF, 0.85 ml, 1.7 mmol) dropwise over 0.5 h. After a total of 1.5 h, add CH<sub>3</sub>OH followed by HCl (1 N) and extract the reaction mixture with EtOAc to obtain 1-(4-fluorophenyl)-3(R)-[3(S)-(4-fluorophenyl)-3-hydroxypropyl]-4(S)-[4-(phenylmethoxy)phenyl]-2-azetidinone (compound 6A-1) as an oil. <sup>1</sup>H in CDCl<sub>3</sub> δ H3 = 4.68, J = 2.3 Hz. CI (M<sup>+</sup>H) 500.

[0105] Use of (S)-tetra-hydro-1-methyl-3,3-diphenyl-1H,3H-pyrrolo-[1,2-c][1,3,2] oxazaborole gives the corresponding 3(R)-hydroxypropyl azetidinone (compound 6B-1). <sup>1</sup>H in CDCl<sub>3</sub> δ H3 = 4.69, J = 2.3 Hz. CI (M<sup>+</sup>H) 500.

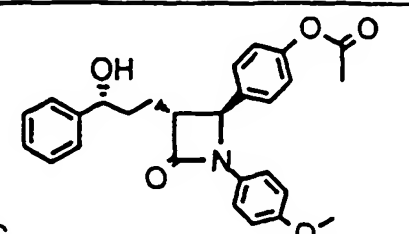
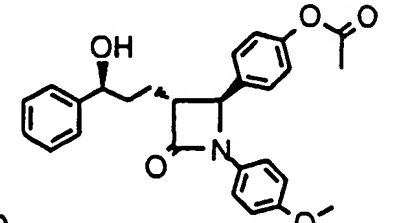
[0106] To a solution of compound 6A-1 (0.4 g, 0.8 mmol) in ethanol (2 ml), add 10% Pd/C (0.03 g) and stir the reaction under a pressure (60 psi) of H<sub>2</sub> gas for 16 h. Filter the reaction mixture and concentrate the solvent to obtain compound 6A. Mp 164-166°C; CI (M<sup>+</sup>H) 410.

[0107] Similarly treat compound 6B-1 to obtain compound 6B. Mp 129.5-132.5°C; CI (M<sup>+</sup>H) 410. Elemental analysis calc'd for C<sub>24</sub>H<sub>21</sub>F<sub>2</sub>NO<sub>3</sub>: C 70.41; H 5.17; N 3.42; found C 70.25; H 5.19; N 3.54.

[0108] Similarly treat compound 6B-1 to obtain compound 6B. Mp 129.5-132.5°C; CI (M<sup>+</sup>H) 410. Elemental analysis calc'd for C<sub>24</sub>H<sub>21</sub>F<sub>2</sub>NO<sub>3</sub>: C 70.41; H 5.17; N 3.42; found C 70.30; H 5.14; N 3.52.

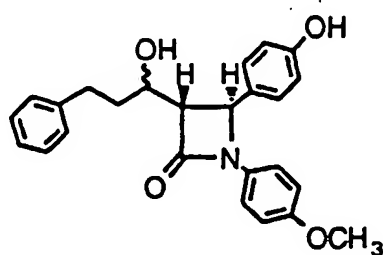
[0108] Step 6') (Alternative): To a solution of the product of Step 5 (0.14 g, 0.3 mmol) in ethanol (2 ml), add 10% Pd/C (0.03 g) and stir the reaction under a pressure (60 psi) of H<sub>2</sub> gas for 16 h. Filter the reaction mixture and concentrate the solvent to afford a 1:1 mixture of compounds 6A and 6B.

[0109] Using appropriate starting materials and following the procedure of steps 1-6, prepare the following compounds:

<p>5</p> <p>10</p> <p>6C</p> 	<p>CI (M+H) 446; HRMS calc'd for C<sub>27</sub>H<sub>27</sub>NO<sub>5</sub> = 445.1904, found 445.1890</p>
<p>15</p> <p>20</p> <p>6D</p> 	<p>CI (M+H) 446; HRMS calc'd for C<sub>25</sub>H<sub>25</sub>NO<sub>4</sub> = 445.1904, found 445.1911</p>

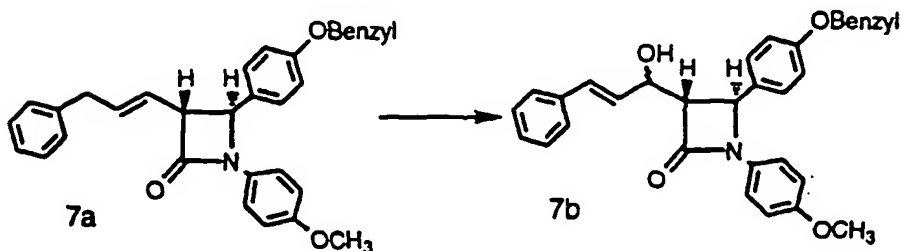
## EXAMPLE 7

[0110]



Step 1):

[0111]



50 To a solution of 7a (1.0 g, 2.1 mmol) in dioxane (10 ml), add SeO<sub>2</sub> (1.33 g, 11.98 mmol) and water (0.25 ml, 14 mmol), and heat the reaction to 100°C. After 1 h, cool the reaction to room temperature and isolate by extraction the crude product as a diastereomeric mixture (1:2) of alcohols 7b-A and 7b-B. Purify by HPLC on a Dynamax silica column to separate diastereomers 7b-A and 7b-B.

55 [0112] Diastereomer 7b-A (R): oil; J<sub>34</sub>=2.3 Hz, δ CH(OH) = 4.86 (t);  
HRMS C<sub>32</sub>H<sub>29</sub>NO<sub>4</sub> calc.: 491.2097; found: 491.2074.

[0113] Diastereomer 7b-B (S): oil; J<sub>34</sub>=2.3 Hz, δ CH(OH) = 5.06 (t);  
HRMS C<sub>32</sub>H<sub>29</sub>NO<sub>4</sub> calc.: 491.2097; found: 491.2117.



[0114] Step 2): To a solution of diastereomer A from step 1 (58 mg, 0.12 mmol) in EtOAc (2 ml), add 10% Pd on carbon (20 mg) and stir at 22°C under H<sub>2</sub> gas (14 psi) for 12 h. Filter and concentrate to obtain the title compound as a semisolid, m.p. 90-92°C.  $J_{34}=2.3$  Hz,  $\delta$  CH(OH) = 4.1 (m); HRMS C<sub>25</sub>H<sub>25</sub>NO<sub>4</sub> calc.: 403.1783; found: 403.1792.

# EXAMPLE 8

[0115] To a solution of the product of Example 4A (90 mg, 0.2 mmol) in CH<sub>2</sub>Cl<sub>2</sub>, add acetyl chloride (80 mg, 1.0 mmol) and pyridine (8 mg, 0.1 mmol) and stir at room temperature for 1 h. Add water, separate the layers and isolate the corresponding acetoxy compound, 8A. In a similar manner, treat the products of Examples 4B, 6B and 6A to obtain the following compounds 8B, 8C and 8D, respectively:

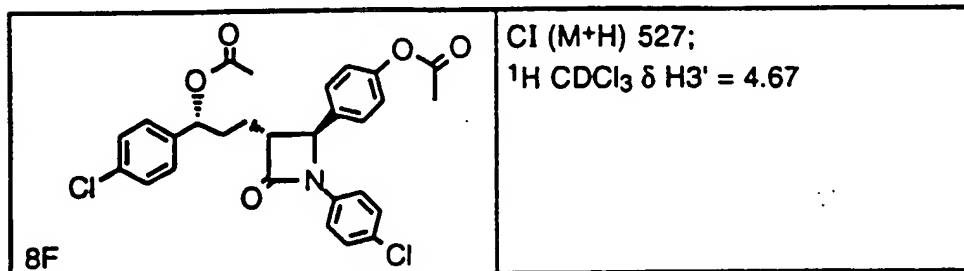
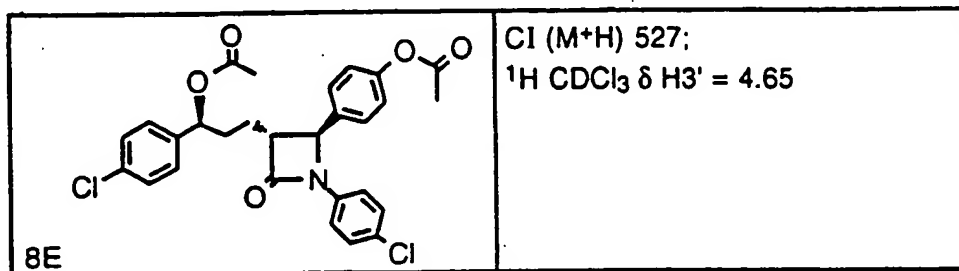
8A: 1,4(S)-bis(4-methoxyphenyl)-3(R)-(3(R)-acetoxy-3-phenylpropyl)-2-azetidinone. CI (M<sup>+</sup>H) 460; HRMS C<sub>28</sub>H<sub>29</sub>NO<sub>5</sub> calc.: 459.2044; found: 459.2045.

8B: 1,4(S)-bis(4-methoxyphenyl)-3(R)-(3(S)-acetoxy-3-phenylpropyl)-2-azetidinone. CI (M<sup>+</sup>H) 460; HRMS C<sub>28</sub>H<sub>29</sub>NO<sub>5</sub> calc.: 459.2044; found: 459.2048.

8C: 4(S)-(4-acetyloxyphenyl)-3(R)-(3(R)-acetyloxy-3-(4-fluorophenyl)propyl)-1-(4-fluorophenyl)-2-azetidinone. FAB MS 493.4; HRMS C<sub>28</sub>H<sub>25</sub>F<sub>2</sub>NO<sub>5</sub> calc.: 493.1695; found: 493.1701.

8D: 4(S)-(4-acetyloxyphenyl)-3(R)-(3(S)-acetyloxy-3-(4-fluorophenyl)propyl)-1-(4-fluorophenyl)-2-azetidinone. FAB MS 493.4; HRMS C<sub>28</sub>H<sub>25</sub>F<sub>2</sub>NO<sub>5</sub> calc.: 493.1695; found: 493.1694.

[0116] Using appropriate starting materials in the procedure of Example 6, prepare 1-(4-chlorophenyl)-3(R)-(hydroxy-3-(4-chlorophenyl)propyl)-4(S)-(4-hydroxyphenyl)-2-azetidinone. Using the procedure of Example 8, prepare the following diacetates 8E and 8F:

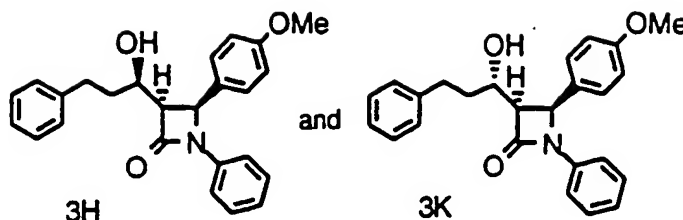


## EXAMPLE 9

[0117]

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[0118] Step 1: Add pyridinium chlorochromate (2.4 g, 11 mmoles) and  $\text{CH}_3\text{CO}_2\text{Na}$  (approx. 20 mg) to a solution of 1-phenyl-3-(3-phenyl-1-hydroxypropyl)-4-(4-methoxyphenyl)-2-azetidinone (2.35 g, 6.1 mmoles) in  $\text{CH}_2\text{Cl}_2$ . Stir at room temperature for 18 h, then add silica gel (40 g) and concentrate to dryness. Flash chromatograph the residue using EtOAc:Hex (1:4) to obtain an oil. (1.98 g, yield =85%).  $^1\text{H}$  NMR 2.85-2.95 (m, 3H), 3.15 (m, 1H), 3.80 (s, 3H), 4.10 (d, 1H, J 2.6), 5.42 (1H, d, J 2.6), 6.85 (dd, 2H, J 2, 8), 7.05 (m, 1H), 7.2-7.35 (m, 11H).

[0119] Step 2: To a solution of the product of Step 1 (1.78 g, 4.62 mmoles) in THF at  $-10^\circ\text{C}$ , add NaH (115 mg, 4.8 mmoles). After 15 min., add NBS (865 mg, 4.85 mmoles) and stir for 20 min., then add 1N HCl and partition between EtOAc and brine. Separate the organic layer, dry ( $\text{MgSO}_4$ ) and concentrate to give an oil. Flash chromatograph the oil using EtOAc:Hex (1:10) to collect first 9a as a foamy solid (830 mg, y=39%, FAB MS 466/464,  $\text{M}^+\text{H}$ ), and then 9b as a colorless solid (1.1 g, y=51%, FAB MS 466/464,  $\text{M}^+\text{H}$ ).

[0120] Step 3a: Add  $\text{Mg}(\text{OCOCF}_3)_2 \cdot \text{CF}_3\text{CO}_2\text{H}$  (7.3 ml of 1M solution in  $\text{Et}_2\text{O}$ ) to a solution of 9a (0.68 g, 1.46 mmoles) in THF (5 ml) at  $-50^\circ\text{C}$ . Stir the reaction 5 min., then add t-Bu-NH $_2$ -BH $_3$  (254 mg, 2.92 mmole). After 15 min., allow the reaction to warm to  $0^\circ\text{C}$  over 20 min., add 1N HCl and concentrate in vacuo. Partition the residue between EtOAc and brine. Concentrate the organic layers and dissolve the resultant oil in  $\text{CH}_2\text{Cl}_2$ :CH $_3\text{OH}$  (1:1) and add ethanolamine (approx 2 mmoles). After 15 min., concentrate the reaction mixture and partition the residue with EtOAc:1N HCl. Wash (brine) and dry ( $\text{MgSO}_4$ ) the organic layer to obtain an oil. Purify this oil by flash chromatography using EtOAc:Hex (1:4) to obtain compound 9a-1, a colorless solid, as a 4:1 mix of diastereomers. 0.52 g, y = 76%, SIMS 468/466 ( $\text{M}^+\text{H}$ ).

[0121] Step 3b: Using compound 9b as the starting material, use a procedure similar to Step 3a with  $\text{CH}_2\text{Cl}_2$  as solvent for the preparation of 9b-1 in 80% yield as a 13:1 mixture of diastereomers (SIMS 468/466  $\text{M}^+\text{H}$ ).

[0122] Step 4a: Add a solution of 9a-1 (0.27 g, 0.58 mmoles) and AIBN (18 mg, 0.12 mmole) in toluene (40 ml) dropwise over 40 min. to a solution of  $(\text{TMS})_3\text{SiH}$  (1.0 ml) in toluene at  $80^\circ\text{C}$ . After 1 h, add more AIBN (5 mg) and continue at  $80^\circ\text{C}$  for 1.5 h. Cool and concentrate the reaction mixture, dissolve the residue in  $\text{CH}_3\text{CN}$  and wash 3x with hexane. Concentrate the  $\text{CH}_3\text{CN}$  layer to give the title compound as a racemic mixture (0.25g). Purify this oil by HPLC using a Chiralcel OD column to obtain 3H (major) and 3J (minor).

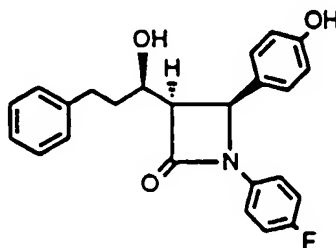
[0123] Step 4b: Use the procedure of Step 4a, starting with compound 9b-1 to obtain an oil. Purify this by flash chromatography using EtOAc:Hex (1:3) to collect the racemic title compound (y=70%). Purify this oil by HPLC using a Chiralcel OD column to obtain 3J (major) and 3H (minor).

## EXAMPLE 10

[0124]

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[0125] Step 1: Follow the procedure of Example 3, using 1-(4-fluorophenyl)-4-(4-t-butyltrimethylsilyloxyphenyl)-2-azetidinone to obtain 1-(4-fluorophenyl)-3-(3-phenyl-1-hydroxypropyl)-4-(4-t-butyltrimethylsilyloxyphenyl)-2-azetidinone.

[0126] Step 2: Treat a solution of the cis-azetidinone of Step 1 (0.25 g) in  $\text{CH}_3\text{CN}$  (21 ml) with 48% aqueous HF (2.5

ml). After 18 h, dilute the reaction mixture with cold H<sub>2</sub>O and extract with Et<sub>2</sub>O. Wash (2x H<sub>2</sub>O, dilute NaHCO<sub>3</sub> and brine), dry (MgSO<sub>4</sub>) and concentrate the Et<sub>2</sub>O layer. Crystallize the residue from EtOAc:hexane (1:2) to obtain the title compound as colorless needles (123 mg, y=64%), mp 168-171°C. Elemental analysis calc for C<sub>24</sub>H<sub>22</sub>O<sub>3</sub>FN: C 73.64; H 5.66; N 3.58. found C 73.32; H 5.65; N 3.68.

- 5 [0127] The following formulations exemplify some of the dosage forms of this invention. In each the term "active compound" designates a compound of formula I.

#### EXAMPLE A

10 [0128]

Tablets			
No.	Ingredient	mg/tablet	mg/tablet
1	Active Compound	100	500
2	Lactose USP	122	113
3	Corn Starch, Food Grade, as a 10% paste in Purified Water	30	40
4	Corn Starch, Food Grade	45	40
5	Magnesium Stearate	<u>3</u>	<u>7</u>
	Total	300	700

#### Method of Manufacture

- 25 [0129] Mix Item Nos. 1 and 2 in suitable mixer for 10-15 minutes. Granulate the mixture with Item No. 3. Mill the damp granules through a coarse screen (e.g., 1/4", 0.63 cm) if necessary. Dry the damp granules. Screen the dried granules if necessary and mix with Item No. 4 and mix for 10-15 minutes. Add Item No. 5 and mix for 1-3 minutes. Compress the mixture to appropriate size and weight on a suitable tablet machine.

#### EXAMPLE B

30 [0130]

Capsules			
No.	Ingredient	mg/tablet	mg/tablet
1	Active Compound	100	500
2	Lactose USP	106	123
3	Corn Starch, Food Grade	40	70
4	Magnesium Stearate NF	<u>4</u>	<u>7</u>
	Total	250	700

#### Method of Manufacture

- 45 [0131] Mix Item Nos. 1, 2 and 3 in a suitable blender for 10-15 minutes. Add Item No. 4 and mix for 1-3 minutes. Fill the mixture into suitable two-piece hard gelatin capsules on a suitable encapsulating machine.
- [0132] Representative formulations comprising a cholesterol biosynthesis inhibitor are well known in the art. It is contemplated that where the two active ingredients are administered as a single composition, the dosage forms disclosed above for substituted azetidinone compounds may readily be modified using the knowledge of one skilled in the art.
- 50 [0133] Using the test procedures described above, the following *in vivo* data were obtained for the exemplified compounds. Data is reported as percent change (i.e., percent reduction in cholesterol esters) versus control, therefore, negative numbers indicate a positive lipid-lowering effect.

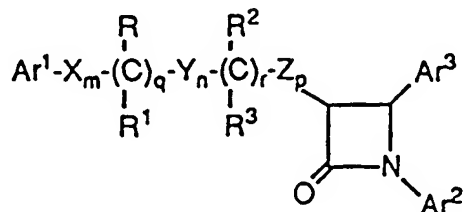
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Ex. #	% Reduction		Dose mg/kg
	Serum Cholest.	Cholest. Esters	
1A	-23	0	50
1B	-15	-39	50
1C	14	0	50
2	0	0	50
3A	-31	-69	50
3C	-60	-92	50
3D	-17	-61	10
3E	0	0	10
3F	-29	-77	10
3G	-16	-38	10
3H	-41	-86	10
3I	0	-22	10
3J	0	0	3
3K	0	0	10
3L	-15	-21	10
3M	0	-22	10
4A	0	-54	5
4B	-37	-89	8

Ex. #	% Reduction		Dose mg/kg
	Serum Cholest.	Cholest. Esters	
4C	-12.5	0	3
4D	9	0	7
4E	0	-46	3
4F	-29	-95	3
5	0	-64	10
6A	-59	-95	1
6A-1	-43	-93	1
6B	-40	-92	3
6C	0	-48	3
6D	-46	-95	10
8A	0	-44	3
8B	-50	-95	3
8C	-14	-37	1
8D	-49	-98	1
8E	-22	-66	3
8F	-43	-94	1
10	-26	-77	3

# Claims

1. A compound represented by the formula



or a pharmaceutically acceptable salt thereof, wherein:

Ar<sup>1</sup> and Ar<sup>2</sup> are independently selected from the group consisting of aryl and R<sup>4</sup>-substituted aryl;  
 Ar<sup>3</sup> is aryl or R<sup>5</sup>-substituted aryl;  
 X, Y and Z are independently selected from the group consisting of -CH<sub>2</sub>-, -CH(C<sub>1</sub>-C<sub>6</sub> alkyl)- and -C(di(C<sub>1</sub>-C<sub>6</sub>) alkyl)-;

R and R<sup>2</sup> are independently selected from the group consisting of -OR<sup>6</sup>, -O(CO)R<sup>6</sup>, -O(CO)OR<sup>9</sup> and -O(CO)NR<sup>6</sup>R<sup>7</sup>;

R<sup>1</sup> and R<sup>3</sup> are independently selected from the group consisting of hydrogen, C<sub>1</sub>-C<sub>6</sub> alkyl and aryl;

q is 0 or 1; r is 0 or 1; m, n and p are independently 0, 1, 2, 3 or 4; provided that at least one of q and r is 1, and the sum of m, n, p, q and r is 1, 2, 3, 4, 5 or 6; and provided that when p is 0 and r is 1, the sum of m, q and n is 1, 2, 3, 4 or 5; and provided that when p is 0 and q is 1, the sum of m, n, and r is 1, 2, 3, 4, or 5.

R<sup>4</sup> is 1-5 substituents independently selected from the group consisting of C<sub>1</sub>-C<sub>6</sub> alkyl, -OR<sup>6</sup>, -O(CO)R<sup>6</sup>, -O(CO)OR<sup>9</sup>, -O(CH<sub>2</sub>)<sub>1-5</sub>OR<sup>6</sup>, -O(CO)NR<sup>6</sup>R<sup>7</sup>, -NR<sup>6</sup>R<sup>7</sup>, -NR<sup>6</sup>(CO)R<sup>7</sup>, -NR<sup>6</sup>(CO)OR<sup>9</sup>, -NR<sup>6</sup>(CO)NR<sup>7</sup>R<sup>8</sup>, -NR<sup>6</sup>SO<sub>2</sub>R<sup>9</sup>, -COOR<sup>6</sup>, -CONR<sup>6</sup>R<sup>7</sup>, -COR<sup>6</sup>, -SO<sub>2</sub>NR<sup>6</sup>R<sup>7</sup>, S(O)<sub>0-2</sub>R<sup>9</sup>, -O(CH<sub>2</sub>)<sub>1-10</sub>-COOR<sup>6</sup>, -O(CH<sub>2</sub>)<sub>1-10</sub>CONR<sup>6</sup>R<sup>7</sup>, -(C<sub>1</sub>-C<sub>6</sub> alkylene)COOR<sup>6</sup>, -CH=CH-COOR<sup>6</sup>, -CF<sub>3</sub>, -CN, -NO<sub>2</sub> and halogen;

R<sup>5</sup> is 1-5 substituents independently selected from the group consisting of -OR<sup>6</sup>, -O(CO)R<sup>6</sup>, -O(CO)OR<sup>9</sup>, -O(CH<sub>2</sub>)<sub>1-5</sub>OR<sup>6</sup>, -O(CO)NR<sup>6</sup>R<sup>7</sup>, -NR<sup>6</sup>R<sup>7</sup>, -NR<sup>6</sup>(CO)R<sup>7</sup>, -NR<sup>6</sup>(CO)OR<sup>9</sup>, -NR<sup>6</sup>(CO)NR<sup>7</sup>R<sup>8</sup>, -NR<sup>6</sup>SO<sub>2</sub>R<sup>9</sup>, -COOR<sup>6</sup>, -CONR<sup>6</sup>R<sup>7</sup>, -COR<sup>6</sup>, -SO<sub>2</sub>NR<sup>6</sup>R<sup>7</sup>, S(O)<sub>0-2</sub>R<sup>9</sup>, -O(CH<sub>2</sub>)<sub>1-10</sub>-COOR<sup>6</sup>, -O(CH<sub>2</sub>)<sub>1-10</sub>CONR<sup>6</sup>R<sup>7</sup>, -(C<sub>1</sub>-C<sub>6</sub> alkylene)COOR<sup>6</sup> and -CH=CH-COOR<sup>6</sup>;

R<sup>6</sup>, R<sup>7</sup> and R<sup>8</sup> are independently selected from the group consisting of hydrogen, C<sub>1</sub>-C<sub>6</sub> alkyl, aryl and aryl-substituted C<sub>1</sub>-C<sub>6</sub> alkyl; and

R<sup>9</sup> is C<sub>1</sub>-C<sub>6</sub> alkyl, aryl or aryl-substituted C<sub>1</sub>-C<sub>6</sub> alkyl wherein aryl is phenyl, naphthyl, indenyl, tetrahydronaphthyl or indanyl.

2. A compound of claim 1 wherein Ar<sup>1</sup> is phenyl or R<sup>4</sup>-substituted phenyl, Ar<sup>2</sup> is phenyl or R<sup>4</sup>-substituted phenyl and Ar<sup>3</sup> is R<sup>5</sup>-substituted phenyl.
3. A compound of claim 2 wherein Ar<sup>1</sup> is R<sup>4</sup>-substituted phenyl wherein R<sup>4</sup> is halogen; Ar<sup>2</sup> is R<sup>4</sup>-substituted phenyl wherein R<sup>4</sup> is halogen or -OR<sup>6</sup>, wherein R<sup>6</sup> is C<sub>1</sub>-C<sub>6</sub> alkyl or hydrogen; and Ar<sup>3</sup> is R<sup>5</sup>-substituted phenyl, wherein R<sup>5</sup> is -OR<sup>6</sup>, wherein R<sup>6</sup> is C<sub>1</sub>-C<sub>6</sub> alkyl or hydrogen.
4. A compound of any of claims 1, 2 or 3 wherein X, Y, and Z are each -CH<sub>2</sub>-; R<sup>1</sup> and R<sup>3</sup> are each hydrogen; R and R<sup>2</sup> are each -OR<sup>6</sup>, wherein R<sup>6</sup> is hydrogen; and the sum of m, n, p, q and r is 2, 3 or 4.
5. A compound of any of claims 1, 2, 3 or 4 wherein m, n and r are each zero, q is 1 and p is 2.
6. A compound of any of claims 1, 2, 3 or 4 wherein p, q and n are each zero, r is 1 and m is 2 or 3.
7. A compound of claim 1 selected from the group consisting of

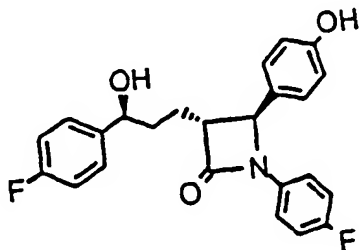
rel 3(R)-(2(R)-hydroxy-2-phenylethyl)-4(R)-(4-methoxyphenyl)-1-phenyl-2-azetidinone;  
 rel 3(R)-(2(R)-hydroxy-2-phenylethyl)-4(S)-(4-methoxyphenyl)-1-phenyl-2-azetidinone;  
 3(S)-(1(S)-hydroxy-3-phenylpropyl)-4(S)-(4-methoxyphenyl)-1-phenyl-2-azetidinone;  
 3(S)-(1(R)-hydroxy-3-phenylpropyl)-4(S)-(4-methoxyphenyl)-1-phenyl-2-azetidinone;  
 3(R)-(1(R)-hydroxy-3-phenylpropyl)-4(S)-(4-methoxyphenyl)-1-phenyl-2-azetidinone;  
 rel 3(R)-[(S)-hydroxy-(2-naphthalenyl)methyl]-4(S)-(4-methoxyphenyl)-1-phenyl-2-azetidinone;  
 rel 3(R)-[(R)-hydroxy-(2-naphthalenyl)methyl]-4(S)-(4-methoxyphenyl)-1-phenyl-2-azetidinone;  
 3(R)-(3(R)-hydroxy-3-phenylpropyl)-1,4(S)-bis-(4-methoxyphenyl)-2-azetidinone;  
 3(R)-(3(S)-hydroxy-3-phenylpropyl)-1,4(S)-bis-(4-methoxyphenyl)-2-azetidinone;  
 4(S)-(4-hydroxyphenyl)-3(R)-(3(R)-hydroxy-3-phenylpropyl)-1-(4-methoxyphenyl)-2-azetidinone;  
 4(S)-(4-hydroxyphenyl)-3(R)-(3(S)-hydroxy-3-phenylpropyl)-1-(4-methoxyphenyl)-2-azetidinone;  
 rel 3(R)-[3(RS)-hydroxy-3-[4-(methoxymethoxy)-phenyl]propyl]-1,4(S)-bis-(4-methoxyphenyl)-2-azetidinone;  
 1-(4-fluorophenyl)-3(R)-[3(S)-(4-fluorophenyl)-3-hydroxypropyl]-4(S)-(4-hydroxyphenyl)-2-azetidinone;  
 1-(4-fluorophenyl)-3(R)-[3(R)-(4-fluorophenyl)-3-hydroxypropyl]-4(S)-(4-hydroxyphenyl)-2-azetidinone;  
 4(S)-[4-(acetyloxy)phenyl]-3(R)-(3(R)-hydroxy-3-phenylpropyl)-1-(4-methoxyphenyl)-2-azetidinone;  
 4(S)-[4-(acetyloxy)phenyl]-3(R)-(3(S)-hydroxy-3-phenylpropyl)-1-(4-methoxyphenyl)-2-azetidinone;  
 1-(4-fluorophenyl)-3(R)-[3(S)-(4-fluorophenyl)-3-hydroxypropyl]-4(S)-[4-(phenylmethoxy)phenyl]-2-azetidinone;  
 3(R)-[3(R)-acetyloxy]-3-phenylpropyl]-1,4(S)-bis-(4-methoxyphenyl)-2-azetidinone;  
 3(R)-[3(S)-acetyloxy]-3-phenylpropyl]-1,4(S)-bis-(4-methoxyphenyl)-2-azetidinone;  
 3(R)-[3(R)-(acetyloxy)-3-(4-fluorophenyl)propyl]-4(S)-[4-(acetyloxy)phenyl]-1-(4-fluorophenyl)-2-azetidinone;  
 3(R)-[3(S)-(acetyloxy)-3-(4-fluorophenyl)propyl]-4(S)-[4-(acetyloxy)phenyl]-1-(4-fluorophenyl)-2-azetidinone;  
 3(R)-[3(R)-(acetyloxy)-3-(4-chlorophenyl)propyl]-4(S)-[4-(acetyloxy)phenyl]-1-(4-chlorophenyl)-2-azetidinone;

none;

3(R)-[3(S)-(acetyloxy)-3-(4-chlorophenyl)propyl]-4(S)-[4-(acetyloxy)phenyl]-1-(4-chlorophenyl)-2-azetidinone; and

rel 1-(4-fluorophenyl)-4(S)-(4-hydroxyphenyl)-3(R)-(1(R)-hydroxy-3-phenylpropyl)-2-azetidinone.

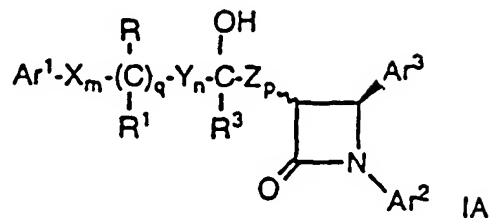
8. A compound according to claim 1, represented by the formula



or a pharmaceutically acceptable salt thereof.

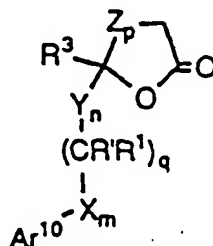
9. A pharmaceutical composition for the treatment or prevention of atherosclerosis, or for the reduction of plasma cholesterol levels, comprising an effective amount of a compound as claimed in any one of claims 1 to 8, alone or in combination with a cholesterol biosynthesis inhibitor, in a pharmaceutically acceptable carrier.
10. The use of a compound as claimed in any one of claims 1 to 8 for the manufacture of a medicament for the treatment or prevention of atherosclerosis, or for the reduction of plasma cholesterol levels.
11. A process for the preparation of a pharmaceutical composition as claimed in claim 9 which comprises admixing a compound as defined in any one of claims 1 to 8 with a pharmaceutically acceptable carrier.
12. A process for preparing a pharmaceutical composition as claimed in claim 9 comprising admixing a cholesterol biosynthesis inhibitor and a compound as defined in any one of claims 1 to 8 with a pharmaceutically acceptable carrier.
13. The use of a compound as claimed in any one of claims 1 to 8 for the manufacture of a medicament for the combined use with a cholesterol biosynthesis inhibitor in the treatment or prevention of atherosclerosis, or for the reduction of plasma cholesterol levels.
14. The use of a cholesterol biosynthesis inhibitor for the manufacture of a medicament for the combined use with a compound as claimed in any one of claims 1 to 8 in the treatment or prevention of atherosclerosis, or for the reduction of plasma cholesterol levels.
15. A kit comprising in separate containers in a single package pharmaceutical compositions for use in combination to treat or prevent atherosclerosis or to reduce plasma cholesterol levels which comprises in one container a pharmaceutical composition comprising an effective amount of a cholesterol biosynthesis inhibitor in a pharmaceutically acceptable carrier, and in a second-container, a pharmaceutical composition comprising an effective amount of a compound as defined in any one of claims 1 to 8 in a pharmaceutically acceptable carrier.
16. A pharmaceutical composition of any of claims 9, 12 or 15 wherein the cholesterol biosynthesis inhibitor is selected from the group consisting of HMG CoA reductase inhibitors, squalene synthesis inhibitors and squalene epoxidase inhibitors.
17. A pharmaceutical composition of claim 16 wherein the cholesterol biosynthesis inhibitor is selected from the group consisting of lovastatin, pravastatin, fluvastatin, simvastatin, CI-981, DMP-565, L-659,699, squalastatin 1 and NB-598.
18. The use as claimed in claim 13 or 14, wherein the cholesterol biosynthesis inhibitor is as defined in claim 16 or claim 17.

19. A process for preparing a compound of the formula



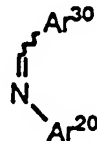
wherein Ar<sup>1</sup>, Ar<sup>2</sup>, Ar<sup>3</sup>, X, Y, Z, R, R<sup>1</sup>, R<sup>3</sup>, m, n, p and q are as defined in claim 1, provided that the sum of m, n, p and q is 1 to 6, comprising:

15 (a) treating with a strong base a lactone of the formula



wherein X, Y, Z, R<sup>1</sup>, R<sup>3</sup>, m, n, p and q are as defined above, R' is a protected hydroxy group, and Ar<sup>10</sup> is Ar<sup>1</sup> as defined above, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl;

30 (b) reacting the product of step (a) with an imine of the formula



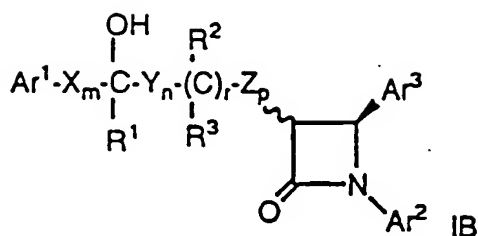
40 wherein Ar<sup>20</sup> is Ar<sup>2</sup>, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl, and Ar<sup>30</sup> is Ar<sup>3</sup>, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl;

c) quenching the reaction with an acid;

45 d) optionally removing the protecting groups from R', Ar<sup>10</sup>, Ar<sup>20</sup> and Ar<sup>30</sup>, when present; and

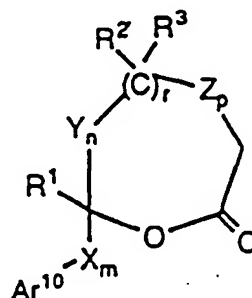
e) optionally functionalizing hydroxy substituents at R and at the carbon to which the R<sup>3</sup> substituent is attached, and hydroxy or amino substituents at any of Ar<sup>1</sup>, Ar<sup>2</sup> and Ar<sup>3</sup>.

50 20. A process for preparing a compound of the formula



wherein Ar<sup>1</sup>, Ar<sup>2</sup>, Ar<sup>3</sup>, X, Y, Z, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, m, n, p and r are as defined in claim 1, provided that the sum of m, n, p and r is 1 to 6, and further provided that when r and n are each zero, p is 1 to 4, comprising:

(a) treating with a strong base a lactone of the formula



wherein X, Y, Z, R<sup>1</sup>, R<sup>3</sup>, m, n, r and p are as defined above; Ar<sup>10</sup> is Ar<sup>1</sup> as defined above, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl; and R<sup>2</sup> is a protected hydroxy group;

(b) reacting the product of step (a) with an imine of the formula



wherein Ar<sup>20</sup> is Ar<sup>2</sup>, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl, and Ar<sup>30</sup> is Ar<sup>3</sup>, a suitably protected hydroxy-substituted aryl or a suitably protected amino-substituted aryl;

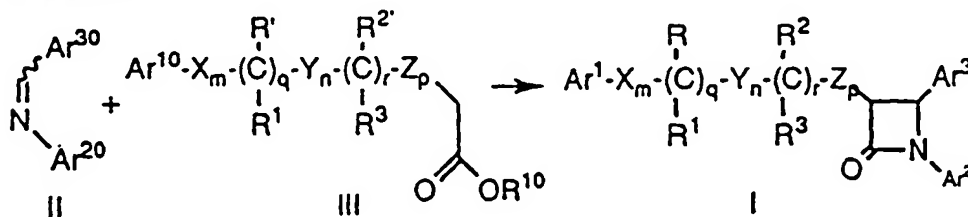
c) quenching the reaction with an acid;

d) optionally removing the protecting groups from R<sup>2</sup>, Ar<sup>10</sup>, Ar<sup>20</sup> and Ar<sup>30</sup>, when present; and

e) optionally functionalizing hydroxy substituents at R<sup>2</sup> and at the carbon to which the R<sup>1</sup> substituent is attached, and hydroxy or amino substituents at any of Ar<sup>1</sup>, Ar<sup>2</sup> and Ar<sup>3</sup>.

21. A process for preparing a compound of claim 1 comprising

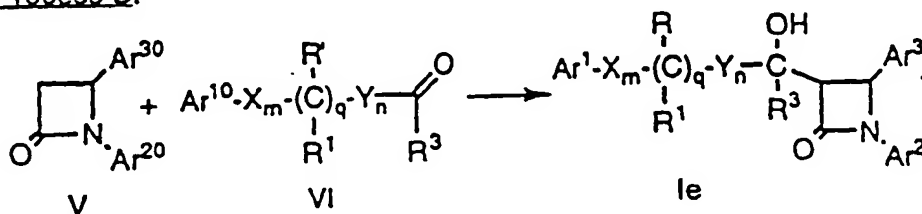
### Process A:





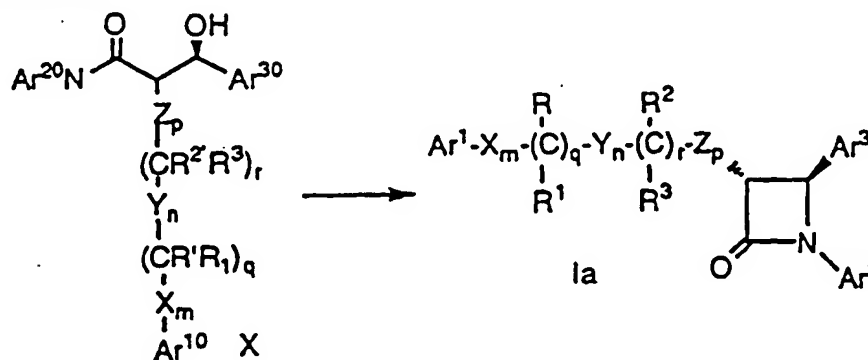
Treating an ester of formula III, wherein  $R^1$ ,  $R^3$ ,  $X$ ,  $Y$ ,  $Z$ ,  $m$ ,  $n$ ,  $p$ ,  $q$  and  $r$  are as defined in claim 1;  $R^1$  and  $Ar^{10}$  are as defined in claim 19;  $R^2$  is as defined in claim 20; and  $R^{10}$  is  $C_1$ - $C_6$  alkyl, menthyl or 10-(diisopropylsulfonamido) isobornyl, with a strong base, and then with an imine of formula II, wherein  $Ar^{20}$  and  $Ar^{30}$  are as defined in claim 19, to obtain a compound of formula I as defined in claim 1; or

### Process B:



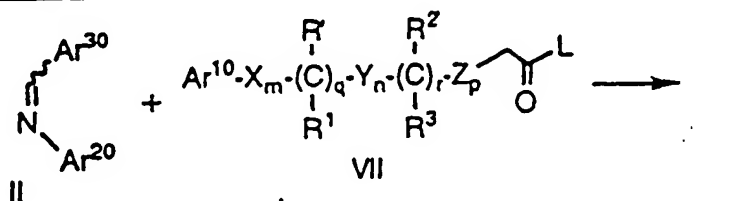
Treating an azetidinone of formula V, wherein  $Ar^{20}$  and  $Ar^{30}$  are as defined in claim 19, with a strong base, then with an aldehyde or ketone of formula VI, wherein  $R^1$ ,  $R^3$ ,  $X$ ,  $Y$ ,  $m$ ,  $n$  and  $q$  are as defined in claim 1 and  $R^1$  and  $Ar^{10}$  are as defined in claim 19, to obtain a compound of formula Ia, which is a compound of formula I wherein  $r$  is 1,  $p$  is 0 and  $R^2$  is OH; or

### Process C:

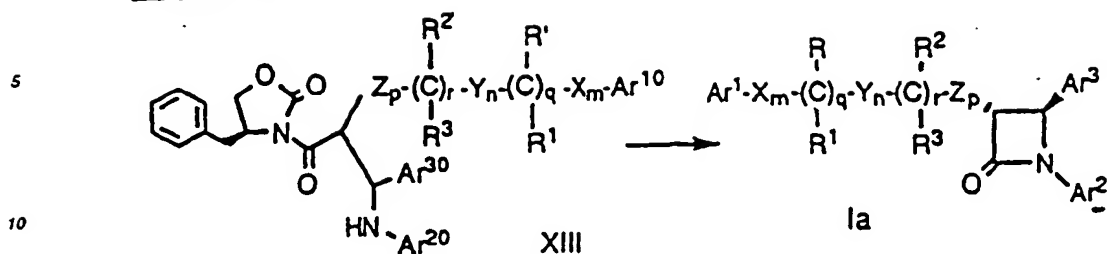


Cyclizing a compound of formula X, wherein the variables are as defined in Processes A and B, above, with a trialkylphosphine and a dialkylazodicarboxylate, to obtain a compound of formula Ia, which is a relative 3,4-trans compound of formula I; or

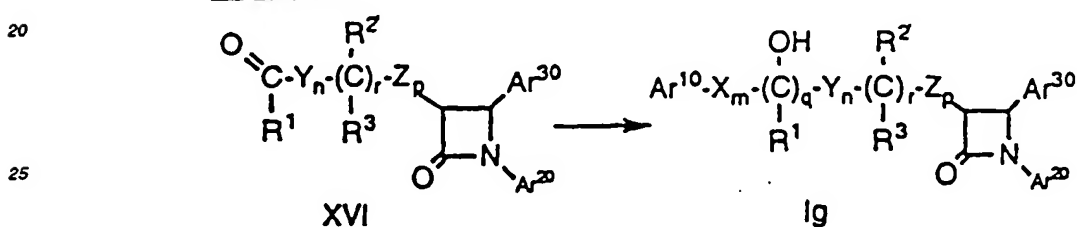
### Process D:



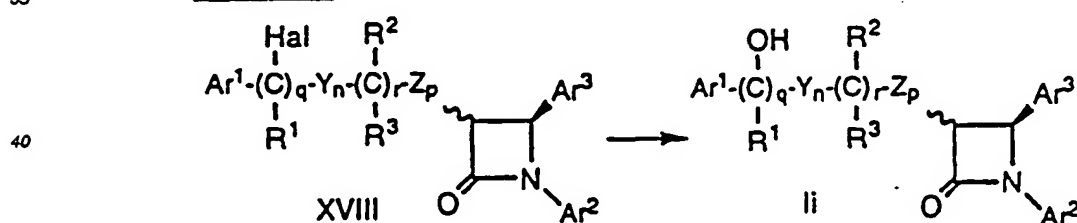
Treating an imine of formula II, wherein  $Ar^{20}$  and  $Ar^{30}$  are as defined in Process A, with an activated carboxylic acid of formula VII, wherein  $L$  is Cl,  $OP(O)(Cl)OPh$ , 2-oxy-N-methylpyridinium iodide or a 2-thiopyridyl ester, and the remaining variables are as defined in Processes A and B, in the presence of a tertiary amine base; or

Process E:

15 Treating a compound of formula XII, wherein the variables are as defined above in Processes A and B, with a strong non-nucleophilic base to obtain a compound of formula Ia, which is a relative 3,4-trans compound of formula I; or

Process F:

30 Treating an aldehyde or ketone of formula XVI, wherein the variables are as defined above in Processes A and B, with an Ar<sup>10</sup>-organometallic reagent, wherein Ar<sup>10</sup> is as defined above in Process A, to obtain a compound of formula Ig, which is a compound of formula I wherein R is OH, optionally followed by the removal of protecting groups; or

Process G:

45 Treating a compound of formula XVIII, wherein Hal is Cl, Br or I and Ar<sup>1</sup>, Ar<sup>2</sup>, Ar<sup>3</sup>, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, Y, Z, q, n, r and p are as defined in claim 1, with a tetraalkyl-ammonium salt or with tetra n-butylammonium trifluoroacetate followed by a mild base, to obtain a compound of formula II, which is a compound of formula I wherein m is 0 and R is OH; or

Process H: